
aerospacesafetyadvisorypanel
A N N U A L R E P O R T F O R 1 9 9 9

"THE PANEL shall review safety studies and operations plans referred to it and shall make reports thereon, shall advise the Administrator with respect to the hazards of proposed or existing facilities and proposed operations and with respect to the adequacy of proposed or existing safety standards and shall perform such other duties as the Administrator may request."

(NASA Authorization Act of 1968, Public Law 90-67, 42 U.S.C. 2477)

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

Reply to Attn of: Q-1

February 2000

Honorable Daniel S. Goldin
Administrator
National Aeronautics and Space Administartion
Washington, DC 20546

Dear Mr. Goldin:

Submitted herewith is the annual report of the Aerospace Safety Advisory Panel for the calendar year 1999. This year we have added explanations in Appendix B of the reasons for classifying NASA's response to last year's recommendations as "open," "continuing," or "closed." We request that NASA re-examine the issues still considered "open" as part of its review of the current submission.

The Panel had productive interactions during the year with both NASA and contractor personnel. Many of the issues resulting from these discussions were closed as part of the Panel's normal fact-finding activities. As a result, there are fewer specific findings and recommendations in this year's report than in last year's.

Overall, it is our assessment that "safety first" is universal within the NASA programs. Safety consciousness, though necessary, is not sufficient to minimize risk. Until there are clear plans, international partner commitments, and adequate funding covering the lifetimes of the Space Shuttle and International Space Station programs, we will remain concerned about their safety over the long-term.

Sincerely,

Richard D. Blomberg

Richard D. Blomberg
Chair
Aerospace Safety Advisory Panel

National Aeronautics and
Space Administration

aerospacesafety advisorypanel

ANNUAL REPORT FOR 1999

February2000

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tableofcontents

I. Introduction 3

II. Findings and Recommendations 9

A. Workforce 11

B. Space Shuttle Program 15

C. International Space Station (ISS) Program .22

D. Extravehicular Activity (EVA) 26

E. Computer Hardware/Software 29

F. Aero-Space Technology 36

III. Information in Support of Findings and Recommendations 45

A. Workforce 47

B. Space Shuttle Program 50

C. International Space Station (ISS) Program .55

D. Extravehicular Activity (EVA) 58

E. Computer Hardware/Software 59

F. Aero-Space Technology 63

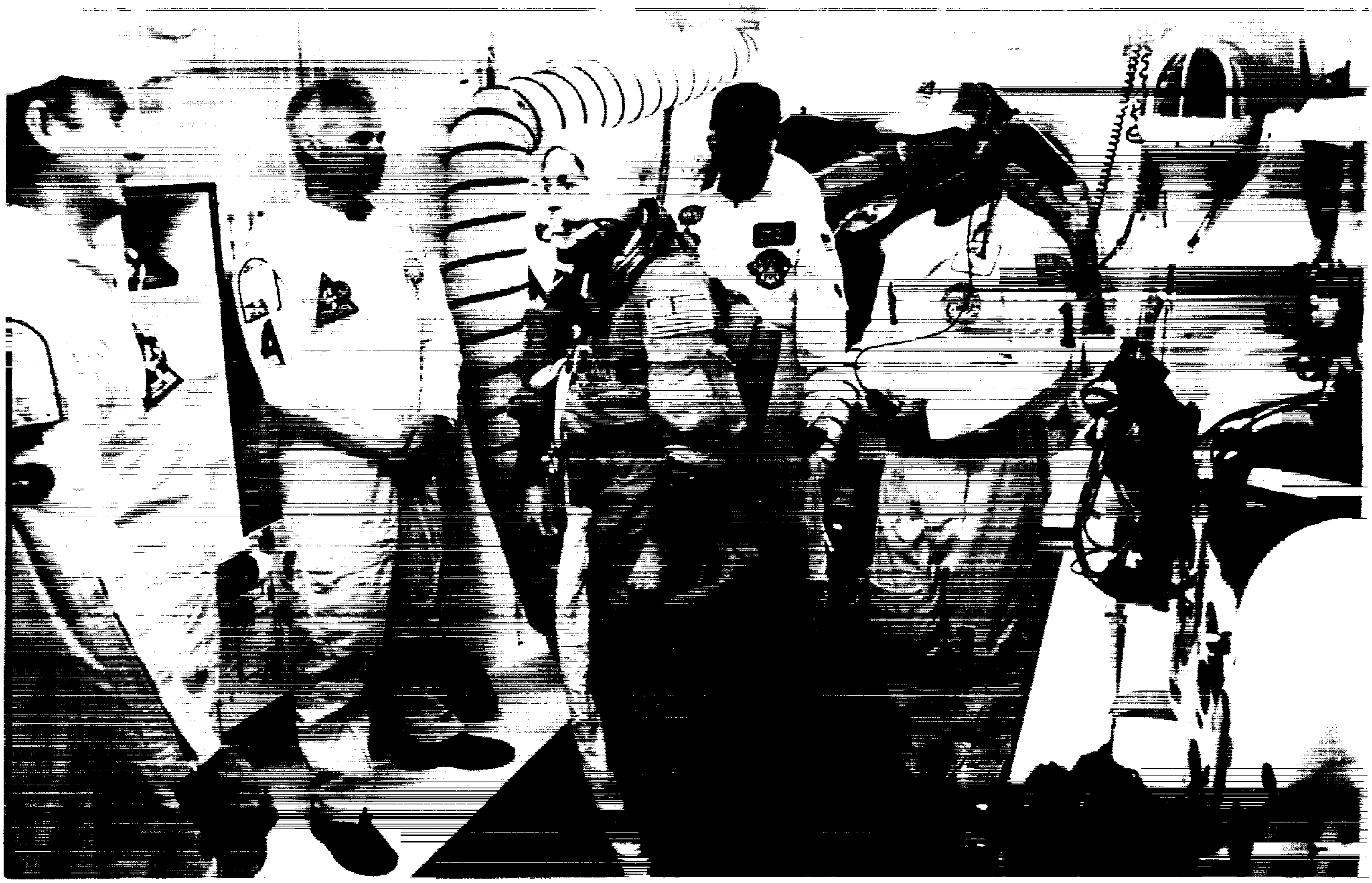
IV Appendices 69

A. Aerospace Safety Advisory Panel Membership 71

B. NASA Response to Annual Report for 1998 .74

C. Aerospace Safety Advisory Panel Activities,

January–December 1999 128



I. Introduction

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This report covers the activities of the Aerospace Safety Advisory Panel (ASAP) for the calendar year 1999. This was a year of notable achievements and significant frustrations. Both the Space Shuttle and International Space Station (ISS) programs were delayed. The Space Shuttle prudently postponed launches after the occurrence of a wiring short during ascent of the STS-93 mission. The ISS construction schedule slipped as a result of the Space Shuttle delays and problems the Russians experienced in readying the Service Module and its launch vehicle.

Each of these setbacks was dealt with in a constructive way. The STS-93 short circuit led to detailed wiring inspections and repairs on all four orbiters as well as analysis of other key subsystems for similar types of hidden damage. The ISS launch delays afforded time for further testing, training, development, and contingency planning.

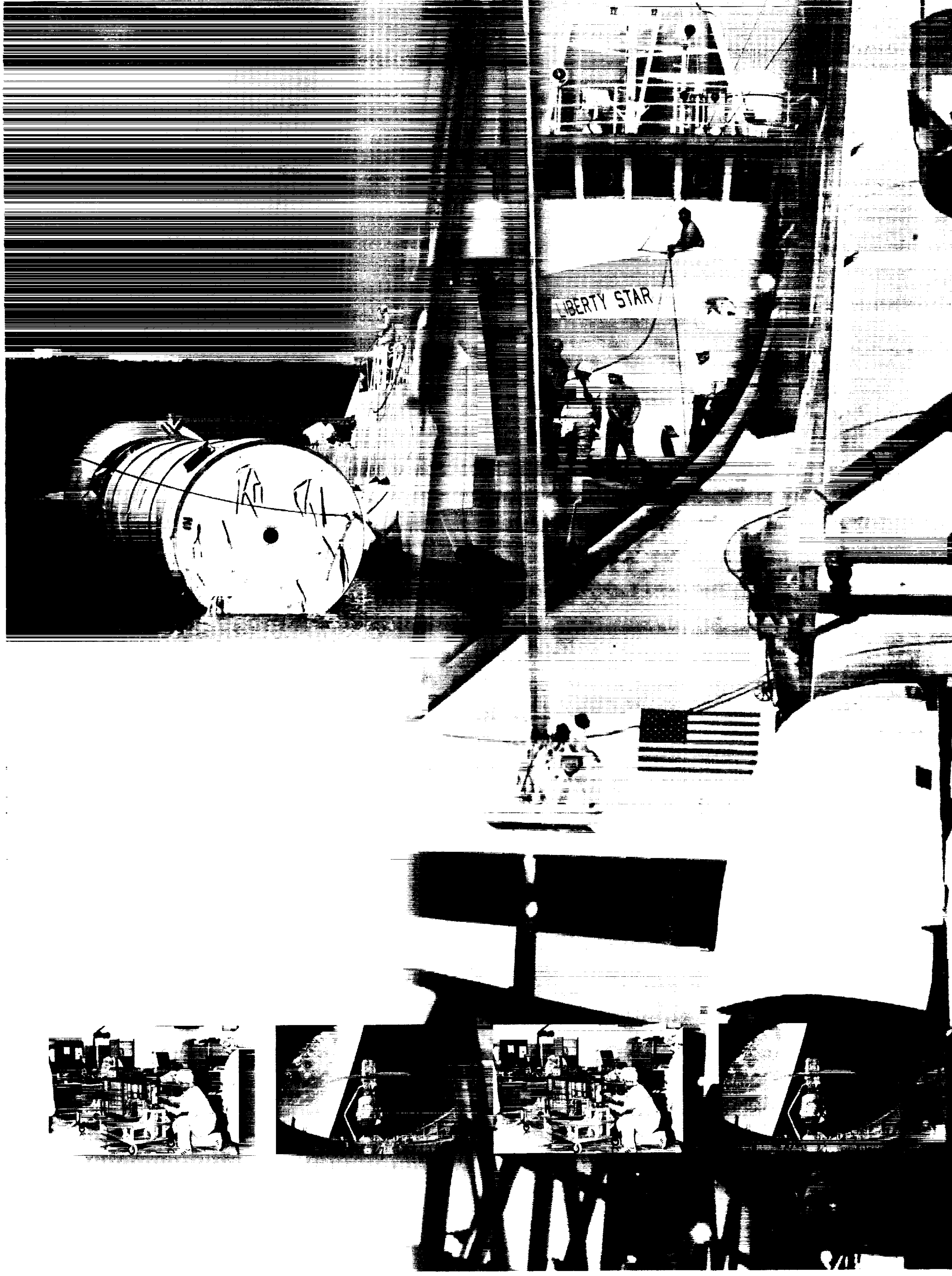
The safety consciousness of the NASA and contractor workforces, from hands-on labor to top management, continues high. Nevertheless, workforce issues remain among the most serious safety concerns of the Panel. Cutbacks and reorganizations over the past several years have resulted in problems related to workforce size, critical skills, and the extent of on-the-job experience. These problems have the potential to impact safety as the Space Shuttle launch rate increases to meet the demands of the ISS and its other customers. As with last year's report, these workforce-related issues were considered of sufficient import to place them first in the material that follows.

Some of the same issues of concern for the Space Shuttle and ISS arose in a review of the launch vehicle for the Terra mission that the Panel was asked by NASA to undertake. Other areas the Panel was requested to assess included the readiness of the Inertial Upper Stage for the deployment of the Chandra X-ray Observatory and the possible safety impact of electromagnetic effects on the Space Shuttle.

The findings and recommendations in this report do not highlight any major, immediate issues that might compromise the safe pursuit of the various NASA programs. They do, however, cover concerns that the Panel believes should be addressed in the interest of maintaining NASA's excellent safety record. The Panel is pleased to note that remedial efforts for some of the findings raised are underway. Given appropriate funding and cooperative efforts among the Administration, the Congress and the various contractors, the Panel is convinced that safety problems can be avoided or solved resulting in lower risk for NASA's human space and aeronautics programs.

Section II of this report contains specific findings and recommendations generated by Panel activities during the calendar year 1999. Section III presents more detailed information in support of these findings and recommendations. A current roster of Panel members, consultants, and staff is included as Appendix A. Appendix B contains NASA's response to the findings and recommendations from the 1998 annual report. It has been augmented this year to include brief explanations of why the Panel classified the NASA response as "open," "continuing," or "closed." Appendix C lists the fact-finding activities of the Panel in 1999.

During the year, Mr. John F. McDonald retired as a consultant to the Panel after distinguished service as both a member and consultant. Mr. Robert B. Sieck, retired Director of Space Shuttle Processing at the Kennedy Space Center (KSC) and Admiral J. Paul Reason (USN, Ret), former Commander-in-Chief, U.S. Atlantic Fleet, joined the Panel as consultants. Mr. Norman B. Starkey left as executive director of the Panel to assume the position of Deputy Associate Administrator for Space Shuttle Operations. Ms. Suzanne E. Hilding, formerly Deputy Director (acting) of Space Shuttle Processing at KSC, succeeded him.


LIBERTY STAR

II. Findings and Recommendations

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A. WORKFORCE

The Panel traditionally has not examined workforce questions in its assessments of the safety of NASA's activities, particularly those associated with human space flight. However, in recent years, NASA and contractor employees have voiced their workforce-related concerns to Panel members during our fact-finding visits to NASA work sites, especially those at Office of Space Flight (OSF) centers—Johnson Space Center (JSC), Kennedy Space Center (KSC), and Marshall Space Flight Center (MSFC). In 1996, the Panel also was asked by the Office of Science and Technology Policy (OSTP) to evaluate the potential safety impacts of ongoing efforts to improve and streamline operations of the Space Shuttle, including the substantial downsizing of NASA's civil service workforce and the transition of many operational responsibilities to the United Space Alliance (USA). In response to this request, the Panel reported its findings and recommendations in the *Review of Issues Associated with Safe Operation and Management of the Space Shuttle Program* (November 1996).

These investigations resulted in specific findings and recommendations that were included in the OSTP-initiated study and in last year's annual report. In the 1997 annual report, the Panel did not make specific findings and recommendations but instead listed six workforce-related "concerns."

An examination of these prior Panel reports reveals several consistent themes, such as:

- Erosion of critical skills and loss of experience at OSF centers;

- A growing lack of younger people at entry-level positions that will lead to a future leadership gap, especially in the "scientists & engineers" (S&Es) classification;

- Insufficient training by both NASA and its contractors to fill the critical skills and experience gaps caused by downsizing;

- A decreasing capacity to accommodate higher Space Shuttle flight rates for a sustained period.

In the past year, NASA has focused increasing high-level attention on these issues. It organized a NASA-wide Core Capability Assessment (CCA), a center-by-center analysis to identify the workforce and infrastructure needed by NASA to carry out its mandated missions. Findings of the CCA were received by the Capital Investment Council and passed on for decision to the Senior Management Council. As discussed below, various positive steps were taken, such as lifting the hiring freeze and strengthening various training initiatives. The CCA continues to pursue these issues.

The Panel recognizes and applauds these positive steps. However, we must also report that, based on our on-site reviews in 1999, workforce issues are not fully resolved. In particular, we have found continuing workforce problems at KSC, JSC, and MSFC related to Space Shuttle operations and the launching of the International Space Station. Similar workforce problems have been reported at other NASA centers, particularly in the areas of flight training and flight testing. The Panel's current findings and recommendations follow.

Finding#1

The continuing downsizing at Office of Space Flight Field Centers, coupled with the effects of the prior hiring freeze and unplanned departures, has produced critical skills deficits in some areas, growing workload pressure and stress levels, and a serious shortfall of younger S&Es.

Recommendation#1

NASA must continue to address workforce problems aggressively and establish program priorities that ensure a workforce capable of achieving long-term safe and effective operations. Emphasis should be placed on eliminating critical skills shortfalls and recruiting younger S&Es who can develop into experienced and skilled future leaders.

Finding#2

The combination of downsizing losses, hiring restrictions, and transition of responsibilities from NASA to contractors, such as USA, continues to limit the opportunities for junior and mid-level NASA managers to gain the operational knowledge and experience required for continued leadership in senior management positions.

Recommendation#2

Innovative arrangements between NASA and its contractors to provide entry-level and mid-level NASA S&Es with operational, "hands-on" experience should be strengthened and expanded. Project management training initiatives, such as the Academy of Program & Project Leadership (APPL), must strive to broaden their outreach to management teams and individuals at the Field Centers.

B. SPACE SHUTTLE PROGRAM

The Space Shuttle government/contractor team continues to mature. Despite difficulties brought about by a lower than expected launch rate, funding uncertainties and an aging system, the team demonstrated that they indeed subscribe to and act in accordance with the principle, "safety first, schedule second."

This is not to say there were not one-time anomalies and continuing problems. Yet, in all cases, a studied and correct course of action was undertaken, and safety was never compromised. In spite of significant pressures, NASA and its contractors employed thorough processes, exercised appropriate engineering judgment, and always maintained the primary importance of safety. That this was so can be attributed to the dedication, teamwork, and decision processes of program personnel. Examples of this are to be found in the systematic and efficient processes used to solve problems such as aging wiring, the ejection of a liquid oxygen post-pin causing a hydrogen leak in a main engine nozzle, and other less spectacular events. The Panel especially applauds the thoroughness of the Orbiter wiring review and further commends USA for conducting a similar review of other critical systems.

Although the Space Shuttle program was successful in 1999, the Panel does have concerns for the future.

There are still too many process escapes, and there is concern about the extent of true insight NASA has into contractor practices.

The aforementioned electrical wiring problem could well be a harbinger of things to come in the aging Orbiter fleet. The Panel hopes that the lessons being learned about aging aircraft at NASA Research Centers, in the airline industry, and in the Department of Defense will be applied to the Orbiter. Meanwhile, the underfunded and slow-paced implementation of the Orbiter Upgrade Program does not bode well for any early improvements. The Panel believes Congress and NASA should pay close attention to the findings and recommendations of the National Research Council's report, *Upgrading the Space Shuttle* (1999).

Special focus must be placed on identifying and eliminating vulnerabilities (such as redundant systems located in close proximity). Additionally, more attention is needed on upgrading avionics as discussed in the Computer Hardware/Software section of this report.

Obsolescence and projected increases in flight rates coupled with longer turnaround times for component repairs cause concern about the ability to support the Space Shuttle manifest.

The lingering effects of workforce downsizing and the uncertainty as to how this downsized and aging workforce will accommodate to the projected increase in launch rate associated with the International Space Station (ISS) are yet to be resolved. In spite of possibly excessive cutbacks, launch processing demands in the short term can be met at an acceptable level of safety risk. This effort, however, will likely further reduce the personnel available to work on productivity enhancements and system life extension activities.

Due to the unusually low recent Space Shuttle flight rate, the reduced workforce has been able to keep up with processing and short-term Ground Support Equipment (GSE) and facility maintenance demands. With future flight rates scheduled to rise to as many as eight per year, with surges equivalent to a rate of 12, this may no longer be the case.

The Panel presents the following as findings worthy of particular attention.

Finding #3

The Space Shuttle Program Office has instituted a set of Process Control Focus Groups whose goal is to implement "best practice" commonality in change control procedures across all supplier tiers.

Recommendation #3

Focus the active and dedicated support of senior management of the major contractors and all their subcontractors on implementing the process control "best practices" as soon as feasible. NASA must be fully apprised of all process changes even if they result in a product that meets requirements.

Finding#4

Although progress has been made to improve the quality, accuracy, and traceability of the work instructions ("paperwork" used in the processing of Space Shuttle Orbiters) much remains to be done to provide correct and unambiguous procedures. There are still too many unincorporated changes.

Recommendation#4

Efforts to improve the quality, accuracy, and traceability of the work paper as well as the timeliness of incorporation of changes to work instructions must be given higher priority by both NASA and USA in a coordinated, systematic effort.

Finding#5

There is no systematic plan to counter obsolescence and assure the availability of adequate facilities, GSE, and specialized test-and-checkout equipment throughout the expected lifetime of the Space Shuttle.

Recommendation#5

Develop and execute a plan to ensure that all needed support and test-and-checkout facilities and equipment are assured available and protected from obsolescence for the maximum foreseeable life of the Space Shuttle.

Finding #6

Space Shuttle processing workload is sufficiently high that it is unrealistic to depend on the current staff to support higher flight rates and simultaneously develop productivity improvements to compensate for reduced head counts. NASA and USA cannot depend solely on improved productivity to meet increasing launch demands.

Recommendation #6

Hire additional personnel and support them with adequate training.

Finding#7

Due to attrition of experienced personnel, NASA and its contractors are assigning more newly trained personnel to Space Shuttle operations tasks. This has led to concerns in the workforce regarding the qualifications of some newly-assigned personnel.

Recommendation#7

NASA and its contractors must ensure that their training, certification, and task assignment processes are such that only suitably qualified engineering and technical personnel are performing Space Shuttle operations. Any training and licensing program to certify new personnel must include both testing of acquired skills and demonstrated proficiency on the assigned task.

C. INTERNATIONAL SPACE STATION (ISS) PROGRAM

The past year has been one of progress and consolidation for the ISS. Experience with the launch and integration of the first several elements into the Multi-Element Integrated Tests (MEIT) and on orbit indicates that the program is well underway and that the overall system is robust. It is encouraging that problems have been found and corrected in MEIT and that planning for the third phase of such testing has begun. This phase will involve the International Partners (IPs) and requires additional funding which the Panel has been given to understand will soon be forthcoming.

The hazard of Micrometeoroids and Orbital Debris (MM/OD) is well recognized. Analyses have been presented which show that the risk is manageable, so long as reasonable precautions are made. Such precautions include avoiding tracked debris, providing sufficient instrumentation to detect and locate penetration of the pressurized modules, training the crew to react quickly in a depressurization emergency, and augmenting the shielding of the Russian Segment on orbit.

It is particularly gratifying to see that an integrated debris tracking and warning system has been created in conjunction with the U.S. Space Command Space Surveillance Network. On one occasion this year, early warning of an impending close encounter was made, and timely, suitable evasive maneuvering was effected, demonstrating the practicability of the system.

Planning and development for caution and warning, damage assessment, and control has come a long way since the Panel first commented on the subject several years ago. The present approach seems reasonable and well thought out, and it is particularly heartwarming to see that the Astronaut Office is fully engaged in its development. Work on a sensor system to localize any sizeable pressure vessel penetration is progressing and, if successful, should lead to a fully engineered and deployed capability.

Overall, the ISS has been progressing productively including addressing items that the Panel had found lagging in previous reports. The majority of issues related to the ISS that the Panel examined during the year were satisfactorily resolved prior to the preparation of this report. The Panel offers the following three findings and recommendations.

Finding #8

Acquisition of the ISS Crew Return Vehicle (CRV) has been lagging and appears to be facing further delay. The full-crew CRV is needed for long-term safe operation of the ISS with a crew larger than three astronauts.

Recommendation #8

Take whatever steps are necessary to halt the delays to the CRV program without jeopardizing adequate demonstration of safety of design and certification of human-rating.

Finding #9

The NASA personnel who are involved in finding solutions for the problems of radiation in space have developed an excellent long-range plan to define approaches for crew protection.

Recommendation #9

Continue to support the nascent, but better defined, radiation effects research and development program.

Finding#10

The Russian Solid Fuel Oxygen Generator (SFOG) is baselined as the backup oxygen supply system for the ISS. This device has experienced problems in its application on Mir and thus may be a potential safety hazard when operated on the ISS.

Recommendation#10

Examine ways to eliminate the risks posed by the use of the Russian SFOG such as by determining the availability of a better, "off-the-shelf," safety-proven SFOG or by initiating an R&D effort to produce a safer alternative.

D. EXTRAVEHICULAR ACTIVITY (EVA)

The timely completion of the very success-oriented ISS assembly schedule depends not on some leading edge of technology, but, rather, on the safe execution, under stressful conditions, of complex mechanical operations by tethered humans in space. Thus, the Panel has taken a special interest in preparations by the EVA Project Office for the impending potentially high-risk program. The ongoing Panel review encompasses equipment, training, and joint U.S.-Russian procedures, ground rules, and protocols. The resultant picture is largely positive in the short-term.

The EVA project has been proactive in addressing the Panel's concerns and planning for safe ISS and Space Shuttle operations. For example, the range of Hard Upper Torso (HUT) sizing will be expanded to include small HUT units. Also, the long-term availability of Simplified Aid for EVA Rescue (SAFER) units on orbit will be assured by the procurement of critical spares and additional flight units.

The long-term picture is less promising. The EVA Research and Technology (R&T) program has suffered a funding cut. This program, when fully funded, had the potential to develop new technologies that would have supported the later years of the ISS and advanced space exploration activities. Extensive planned EVA activity for the ISS, associated wear-and-tear on the equipment and obsolescence render it unrealistic to expect the existing EVA assets to last the entire 15-year projected lifetime of the ISS. While further procurement of existing designs may be possible, it is preferable to incorporate improvements when additional equipment is acquired.

The Panel has two findings in this subject area this year.

Finding #11

The EVA Project Office has several planned initiatives to ensure the availability of adequate EVA resources to support the ISS and Space Shuttle. These initiatives cover acquisition of materiel, development of procedures, and improved training.

Recommendation #11

Expedite completion of the planned initiatives related to the safety of EVA so that maximum benefit can be realized during the upcoming intensive ISS assembly schedule.

Finding #12

The funding of the EVA R&T program is not adequate to provide the maximum safety benefit in terms of new equipment and procedures that lower the risk of extravehicular activities.

Recommendation #12

Fund a robust EVA R&T program.

E. COMPUTER HARDWARE/SOFTWARE

The activities of NASA and its contractors over the past year have been responsive to most of the computer issues raised in last year's report. Many of these issues, however, will take years to fully resolve. The Panel has therefore opted not to revisit these issues in this report although it will continue to monitor future progress. Instead, several new issues that have come to the forefront during the past year will be addressed.

Agency-wide computer security is one such issue. This topic has become important to the Government as a whole, not just NASA. NASA has taken a number of positive initial steps toward identifying the extent of the problem and instituting mechanisms to deal with it. However, these steps will take several years to fully deploy. The Panel has several recommendations in support of these efforts, both at the agency-wide level and for specific projects.

Secondly, this report addresses a pair of issues regarding avionics upgrades to the Space Shuttle. Some excellent plans have been developed for overcoming avionics obsolescence problems. The Panel supports moving ahead with most of these, but suggests careful evaluation of their impact on "Crit 1" (risk of loss of life) functions.

Finally, we raise a concern about incident investigation and long-term operability of the ISS.

One point not covered by a specific finding and recommendation relates to the Schedule Release Control Board (SRCB) developed by the ISS program to assist timely software delivery. The SRCB has proven to be an effective mechanism for managing schedules and preventing last minute problems. This concept might profitably be applied to other major software programs within the Agency.

Finding#13

NASA has taken positive steps for upgrading security on the ISS uplink by adopting a more robust encryption scheme. The downlink and the links between the Mission Control Centers (MCCs) in Houston and Moscow, however, are not encoded.

Recommendation#13

Conduct an overall threat analysis of the Space Station downlink and its interfaces to both MCC Houston and MCC Moscow.

Finding#14

NASA has initiated an agency-wide program to deal with general computer security. Significant parts of NASA's initial plan depend upon the voluntary compliance of system users including contractors.

Recommendation#14

Expand the agency-wide security system development work to include less dependence on human compliance with the system. NASA should also require contractors to participate in its security efforts.

Finding #15

Further analysis of NASA's planned agency-wide computer security system is needed to understand its vulnerabilities and the programs and activities to which the system should be applicable.

Recommendation #15

Conduct a thorough analysis, together with the National Security Agency, to determine the level of computer security required by the Agency, the level of security that can be expected from the system and its most serious vulnerabilities. Also require all major mission or safety critical programs to have a qualified third party conduct a computer vulnerability analysis of their designs as soon as possible.

Finding #16

NASA has established an Avionics Upgrade Architecture Team (AUAT) charged with studying Space Shuttle avionics systems and recommending upgrades. The AUAT has conducted a thorough study and developed an excellent Block I upgrade plan that addresses the most serious needs, but as yet it is unfunded.

Recommendation #16

Proceed with full funding for the proposed Block I Space Shuttle avionics upgrades as rapidly as possible.

Finding#17

Part of the AUAT's initial approach is to install three mission computers to augment the existing General Purpose Computers (GPCs). The specific functions to be off-loaded from the GPCs to the mission computers have yet to be determined. Eventually, the AUAT plans to consider moving some "Crit 1" functions to the mission computers.

Recommendation#17

Do not move any "Crit 1" functions to the mission computers unless memory requirements in the GPC demand it and then only after an appropriate risk analysis is performed.

Finding#18

The long-term support of the International Partners with respect to software source code is essential to the safe operation of the ISS and the resolution of any software-related anomalies.

Recommendation#18

Solidify long-term source code maintenance and incident investigation agreements for all software being developed by the International Partners as quickly as possible, and develop contingency plans for all operations that cannot be adequately placed under NASA's control.

F. AERO-SPACE TECHNOLOGY

The NASA Aero-Space Technology Enterprise has shifted emphasis from programs connected with aviation to projects focused on space transportation and information systems. At the same time, the funding for the Enterprise has been significantly reduced. A most undesirable result has been a reduction of expenditures on those efforts which have the potential to enhance long-term aviation safety. On the other hand, the talent and enthusiastic dedication to safety of NASA personnel charged with pursuing the Three Pillars for Success strategic plan are undiminished. All they need are the resources to do the job.

Reduced funding for the Three Pillars notwithstanding, there are a number of ongoing NASA aviation research projects which have the potential to enhance aviation safety. Some examples are the Aircraft Performance and Monitoring System, crew fatigue studies, and next generation "Intelligent Flight Control" efforts. The latter employs a neural network system which can automatically compensate for a broad spectrum of aircraft problems and malfunctions. Closely allied with the Intelligent Flight Control System is the quadruple redundant digital flight control system on the "ACTIVE" aircraft.

The Intelligent Synthesis Environment (ISE) program holds much promise, but clear goals seem to be lacking.

Key to many NASA, academic, and private sector efforts to enhance flight safety are the NASA wind tunnels. Yet, aside from the potential deterioration of these national resources due to underfunding, an immediate concern is rooted in the announced intention to cross-train wind tunnel operators. Each installation is unique, and the Panel is skeptical that such cross-training can be maintained without compromising safety.

Finally, in the Space Shuttle program section of this report is a finding on process control. The Aero-Space Technology Enterprise could well follow the example of the Space Shuttle program in ferreting out process control problems. For example, a recent Perseus Unoccupied Air Vehicle (UAV) flight termination failure was traced to a process control problem. It could happen elsewhere.

Beyond the above, the following are the Panel's specific findings and recommendations.

Finding#19

Programs such as the now-defunct High Speed Research and Advanced Subsonic Technology often yield aircraft safety improvements. Elimination of these programs may well be inimical to advances in aviation safety.

Recommendation#19

Identify those elements of the eliminated programs which had the potential to improve aviation safety and cover them elsewhere.

Finding#20

The involvement of Center Directors in aviation flight readiness, flight clearance, and aviation safety review board matters is not uniformly satisfactory.

Recommendation#20

Underscore the need for Center Directors to become involved personally in aviation flight readiness, flight clearance, and aviation safety review board matters.

Finding #21

NASA's responsibilities with regard to aviation flight safety when a contractor conducts flights and/or provides payloads are not clearly defined.

Recommendation #21

Define more explicitly the safety responsibilities of NASA Centers when conducting, supervising, or participating in contractor-operated aviation flight and payload operations.

Finding#22

The chain of safety responsibility for the operation of the Stratospheric Observatory for Infrared Astronomy (SOFIA) aircraft is complex and unclear.

Recommendation#22

Sort out and clear up the SOFIA chain of flight operations safety responsibility.

Finding#23

In planning for SOFIA operations, aviation safety and flight personnel have had minimal involvement.

Recommendation#23

Involve cognizant aviation safety and flight personnel in SOFIA planning and development on a routine basis.

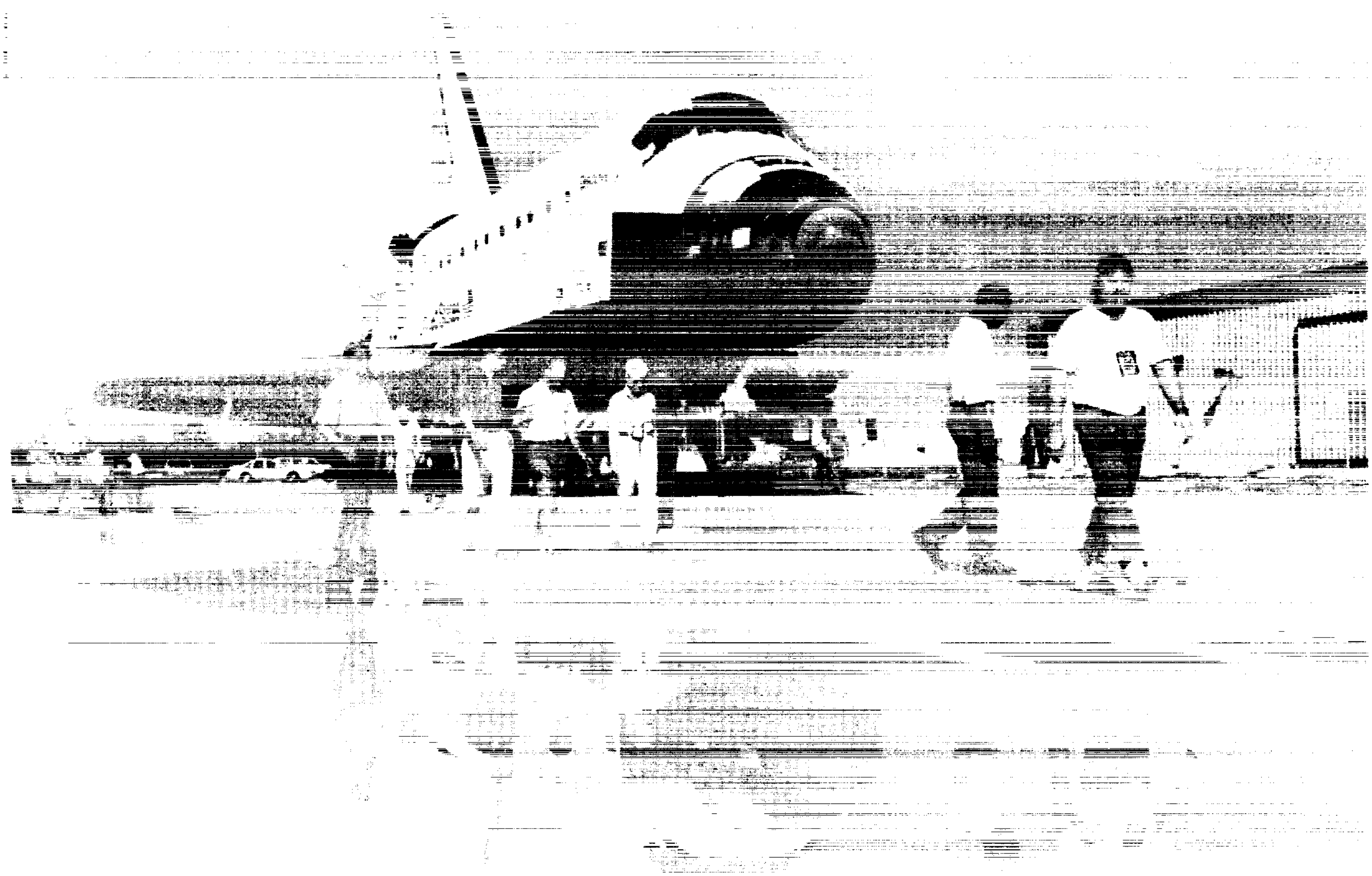
Finding#24

As currently configured, the SOFIA aircraft does not contain avionics consistent with best practices for international operations.

Recommendation#24

Ensure that the SOFIA aircraft is configured in accordance with prevailing international airline avionics practices.

III. Information in Support of Findings and Recommendations



III. Information in Support of Findings and Recommendations

A. WORKFORCE

Ref: Finding #1

In the past year, the workforce issue has received focused attention at the highest levels of NASA. The Core Capability Assessment (CCA) generated an intensive look at the workforce and infrastructure requirements of the Offices and Field Centers in order to carry out their assigned missions. The Office of Space Flight (OSF) Centers reported the most difficulty in meeting their current program responsibilities with the workforce targets established by the Zero Base Review (ZBR) conducted in the mid-1990s. Some marginal adjustments to these workforce targets were recommended by the CCA and approved by the Senior Management Council. These adjustments have had two major impacts: (1) the hiring freeze that essentially stopped all new hires for the OSF ended in favor of a general formula of one new hire for every two additional Full Time Equivalent (FTE) reductions; and (2) the ZBR-mandated workforce ceilings are still in place but their implementation has been stretched out by several years.

Nevertheless, this positive activity did not change the fundamental situation faced at the OSF Centers in carrying out safe and effective operations of the Space Shuttle and the design, verification, launch, and assembly of the International Space Station (ISS). The Panel heard consistent and repeated reports—from high-level administrative leaders to floor-level technicians—of critical skills shortages at the Johnson Space Center (JSC), Kennedy Space Center (KSC), and Marshall Space Flight Center (MSFC), along with a general lack of workforce resources needed to sustain the projected flight rate of the Space Shuttle and the ISS segments. Similar workforce concerns have been reported by other NASA Centers, particularly in the areas of flight training and flight testing. These workforce shortfalls in certain critical skills are also a factor in the questionable capability of the United Space Alliance (USA) to achieve the higher flight rates projected in 2000 and 2001. The Panel has also been assured repeatedly by NASA and USA that under no circumstances will safe operations be sacrificed due to workforce limitations. While the Panel believes this commitment to operational safety is sincere, the increased danger of inadvertent human error in a stressful work environment cannot be ignored.

The reality of a work environment of increasing stress was validated by studies at JSC and MSFC. A Stress Management Advisory Team was established at JSC to examine indicators of stress in the JSC workforce, understand the reasons for stress, and develop recommendations to manage this stress. At MSFC, the Employee Assistance Program has reported a near doubling (from 400 to 700) of stress-related cases from 1997 to 1999.

A final concern of the Panel carried over from prior annual reports is the need to resume active recruitment of the S&Es who will provide a foundation for developing NASA's future leaders. The combination of recent downsizing and the hiring freeze has severely impacted NASA's population of entrance-level S&Es. At KSC there are twice as many S&Es over age 60 than under 30. Although the CCA has resulted in some limited new hires, these positions have been filled with more senior persons with the higher experience levels needed to fill existing critical skills deficits, rather than "fresh-out" graduates. Eliminating this future leadership gap continues to be a challenge that NASA needs to address. Further, the recently approved hiring formula (one new hire for every two departures) continues the downsizing at the OSF Centers.

Ref: Finding#2

In recent years, the Panel has expressed concern over the effect that downsizing and the transition of NASA responsibilities to contractors has had on the development of highly experienced and knowledgeable senior managers within NASA. As the NASA workforce shifts its focus to providing "insight" of contractor performance, the opportunities to acquire essential "hands-on" knowledge and experience will decline. This decline potentially can inhibit the ability of future senior managers to ensure the safe and effective conduct of NASA programs.

In the past year, the Panel has learned of positive steps underway to deal proactively with this situation. With the complete lifting of the hiring freeze (although OSF Centers are still limited to one new hire for every two FTE reductions), the focus has officially shifted from downsizing to "revitalization" of the workforce. Training budgets have been increased across NASA. Travel money is more readily available to permit employees to travel to training sites. Training initiatives, such as the Academy of Program & Project Leadership (APPL), are developing tools to strengthen project management skills of individuals and teams. The CADRE-PM program will make developmental resources available to future leaders. These are needed and worthwhile initiatives.

The Panel has also found that the current impact of these training efforts is limited. From the perspective of the Field Centers, their objectives are applauded but the training programs have yet to achieve a significant impact. The current workload leaves little time for training. The difficulty of capturing and preserving the technical, hands-on knowledge and experience needed by future senior managers is also acknowledged. It was pointed out to the Panel that it is a lot easier to train managers than it is to develop leaders. There is no substitute for the challenges associated with direct, working experience in this leadership development process.

Accordingly, NASA and its contractors, especially USA, must continue to seek various innovative working arrangements that can provide the challenges and opportunities essential to building competent, experienced, and self-confident senior managers, vital components in sustaining safety and effectiveness.

B. SPACESHUTTLEPROGRAM

Ref: Finding#3

A Space Shuttle Program Manager's Review (PMR) held in August 1999 concentrated on current process change control activities and solicited improvements that could be made to achieve commonality across the program. It was noted that some process integrity audits are being conducted, as a part of compliance audits at several subcontractor tier levels, supplemented by face-to-face visits with subcontractors by prime contractors. A significant outcome of the PMR was to drive toward applying commonality of process change control across the program as a whole. The PMR recognized the need for a message to individual employees that process control is a critical activity in maintaining Space Shuttle safety. The Panel has participated with NASA and USA in visiting a sample of lower tier subcontractors on the program. Some of these subcontractors were small shops with less than 50 employees. It was encouraging to find that these subcontractors were keenly aware that their product was to be used on human space flight vehicles, and that conformance to the procedures and requirements specified was mandatory in order to maintain Space Shuttle performance and reliability.

For example, in consonance with the PMR, Thiokol had already implemented a program of Process/Product Integrity Audits (PPIA). These are line-by-line self-audits of the procedures which implement a process to insure that the intent of the procedure is understood and workable. That review is conducted by the Thiokol users and owners of the process with NASA participation. Thiokol has encouraged their lower tier subcontractors to conduct this same type of audit and has received favorable results.

Thiokol has also begun to apply the Failure Modes and Effects Analysis (FMEA) discipline to their manufacturing processes. These process FMEAs have identified improvements which are yielding a significant reduction in the number of hardware discrepancies. This activity, and the PPIA methodology, is applicable to the other contractors on the Space Shuttle program, and its implementation should be encouraged.

Ref: Finding#4

As noted in last year's report, there are still many "deviations" and changes in the build paper and procedures not yet incorporated in the work paper. Working with obsolete and/or incorrect work paper is both inefficient and potentially hazardous to personnel and to mission success. There have also been several processing incidents during the year that were traced at least in part to poor paperwork or inadequate paperwork traceability.

USA has undertaken promising paperwork improvements including reformatting of the "procedures" to include extensive use of graphics and digital photography. This should improve the comprehensibility of the instructions and reduce ambiguities. Progress towards the completion of this work has been very slow. Although USA has attempted to communicate the objectives and nature of the proposed changes in format and content to the workforce, many of the "hands-on" personnel have yet to see any of the products of the program. Changes to work instructions must be given higher priority by both NASA and USA in a coordinated, systematic effort. This will be even more important as the launch rate increases to accommodate the Space Station program.

While the paperwork improvement program is vital for the long-term effectiveness of standard launch preparations and operations, there are non-standard situations that demand extra attention and care. For example, the wiring inspection of all the Orbiters required rapid and extensive generation of new work instructions. Careful review of the instructions must be made before implementation, and a system for correct and rapid verification of the validity of proposed changes prior to incorporation must be established.

Ref: Finding#5

Most of the facilities, ground support equipment (GSE), and specialized test and checkout devices used to prepare the Space Shuttle for launch are 20 or more years old. While some Space Shuttle components have been upgraded, the equipment used to check them out or repair them is often still the original. This forces dependence on equipment and facilities that may be approaching obsolescence and may be aging to the point of becoming unreliable.

To date, corrective maintenance has been good, and preventative actions have been sufficient to forestall major problems. It is unlikely, however, that all of the key facilities, GSE, and test equipment can continue to be made available indefinitely without either total replacement or at least upgrading key subsystems or components.

A comprehensive plan to carry the vital components of the Space Shuttle infrastructure across the expected service life of the program has yet to be prepared. Such a plan is needed so that resources can be allocated across multiple years to ensure that all needed improvements and replacements can be executed in a timely manner. The plan should encompass all of the infrastructure and equipment needed by the Space Shuttle at all relevant NASA Centers. It should also detail specific actions, schedules, and budget needs so that there is a clear roadmap to prevent the loss of critical capabilities.

Ref. Finding#6

The NASA and USA workforces at the Kennedy Space Center (KSC) have been downsizing for several years. Further staff reductions are planned to meet arbitrary staffing targets set almost five years ago. Coupled with retirements and unplanned staff departures, this downsizing has led to critical skills shortages among the personnel needed to prepare and launch the Space Shuttle. While requirements for processing have been reanalyzed and reduced somewhat, they have not fallen enough to compensate fully for the loss of personnel.

In recognition of the need to restore launch processing capability after the staff downsizing, USA has initiated a series of productivity enhancements intended to process and launch more Space Shuttles with a smaller staff. These initiatives include items such as the introduction of new software to automate tasks previously accomplished manually, revised scheduling methods, and more standardized work instructions.

The reduced capacity to process and launch Space Shuttles has not presented an operational or safety problem over the past two years as flight rates have been low, and intervals between flights have been quite long. Future manifests place far greater demands on the launch processing system. In particular, the ISS construction sequence requires launching the 3A, 4A, and 5A increments at approximately one-month intervals. This is an effective launch rate of 12 per year. A launch rate of this magnitude will likely cause problems for both NASA and USA unless their personnel resources are augmented.

Although promising in the long term, USA productivity initiatives have yet to mature to the point where they can compensate for the loss of personnel. One of the problems is that the same experienced people who are the prime team for launch processing are needed to develop, test, and implement the productivity enhancements. This further increases their workload and delays the time when the initiatives will be on-line.

In light of this situation, it seems prudent not to rely solely on productivity enhancements to meet increased flight rates. NASA and USA should increase staffing and/or rearrange the Space Shuttle flight manifest to ensure that sufficient trained and experienced personnel are available for processing using the current procedures while simultaneously maintaining a core of these individuals working on productivity improvements.

Ref. Finding#7

NASA and its contractors have reduced their engineering, technician, and inspector workforces. This has resulted in skills shortfalls in certain areas. In addition, the anticipated Space Shuttle flight rate represents an increase in launches that will require USA to add staff to meet planned and unexpected processing demands.

The demands on experienced personnel can be expected to mount as attrition continues, the flight rate increases and the amount of non-standard processing work rises. The current commitment and sensitivity to safety is high, and personnel indicate they will stop if they are unsure about proceeding with operations tasks. While this discipline is currently in place, it will be tested more and more as the flight rate and inevitable schedule pressures increase. This issue was raised in the Panel's 1998 annual report.

In response to the need for additional personnel with specific skills, USA has initiated training programs. These are applied to new hires, transfers from other skill areas, and as cross-training for workers who will carry multiple certifications. This is basically a sound approach to building a more flexible and robust skills inventory. The problem, however, is that many Space Shuttle engineering and technical tasks are relatively unique in the aerospace industry. They are best learned through a combination of training and a mentoring or apprenticeship process in which the new worker has the opportunity to become proficient at the task under the supervision of an experienced colleague.

At present, newly trained and certified employees are not prohibited from performing tasks alone or as the lead person on a team. It seems only prudent that the long-standing Space Shuttle practice of transitioning trainees into a task under supervision be institutionalized as a requirement. This will ensure that everyone working on the Space Shuttle has both adequate training and sufficient experience to perform the task properly and thereby preserve the safety of the system.

It also must be noted that the training situation will become particularly difficult for NASA whose personnel have transitioned away from the "hands on" operations where most of their skills where obtained.

C. INTERNATIONAL SPACE STATION (ISS) PROGRAM

Ref: Finding #8

The Panel has continuously supported the need for the development and procurement of a full-crew Crew Return Vehicle (CRV) for the ISS. Safe operation of the ISS with more than a three-person crew will not be possible until such a CRV is available. This is stipulated in the mission operating rules.

The present deployment plans call for a U.S. CRV with a seven-person capacity together with a Soyuz vehicle that is limited to three passengers. In addition, each of the Soyuz occupants must have an individually fitted seat liner. This limits the flexibility of return operations.

There is an uncertain supply of Soyuz vehicles, which must be exchanged every six months while on orbit. The CRV procurement has been delayed. This situation could bring additional pressure to accelerate the vehicle and human-rating certification processes. This cannot be permitted. While all due haste is needed to acquire the CRV, there can be no shortcuts in certification and human-rating requirements if safety is to be maintained.

In light of these considerations, it is essential to begin the design and acquisition processes for the CRV as expeditiously as possible.

Ref: Finding#9

The hazards to personnel from radiation during space flight appear now to be well recognized. Also acknowledged is the need to go well beyond ALARA ("as low as reasonably achievable") to provide proper protection for our astronauts. Inadequacies in our systems to detect and measure radiation fields, to monitor individual exposure, to construct models capable of predicting solar events, to shield vehicles and space suits with minimum weight penalty, to specify operating procedures that limit radiation exposure, and related topics have been identified for study and development. A sustained, focused, and well-supported program will be required to achieve results that will benefit the ISS in the near term and Mars and beyond in the longer term.

Ref: Finding#10

The Russian Solid Fuel Oxygen Generator (SFOG) proposed for use on the ISS as a backup source of oxygen has a star-crossed history, having caused a serious fire on Mir. Recent tests have revealed that the Russian SFOG unit can reach temperatures capable of melting the steel canister, and there is a susceptibility to react to contaminants. A suitable replacement system may be available/adaptable from commercial aviation or submarine applications. If not, NASA, perhaps in conjunction with other potential users, should develop a safer standby oxygen source for the ISS.

D. EXTRAVEHICULAR ACTIVITY (EVA)

Ref: Findings #11 and #12

Timely and safe execution of the ISS assembly sequence will require near-perfect performance by the EVA team. Differences remain between U.S. and Russian procedures, some equipment and tools are still under development and must be tested, and training must then be completed. Delays to date in the assembly sequence have been fortuitous; now the proposed schedule appears achievable.

For the long-term health of NASA's EVA activities, an aggressive R&T program is needed. This program could profitably focus both on near-term solutions to ISS and Space Shuttle mission requirements as well as on future exploration of space, e.g. a new spacesuit for a planetary mission.

E. COMPUTER HARDWARE/SOFTWARE

Ref: Finding #13

Significant care has been taken to prevent potential security breaches in both the uplink and downlink for the Space Station. As with any complex system involving multinational contracts and relationships, it is impossible to ensure that a determined hacker with adequate resources and incentives could not break into the command link. However, it has not been possible to find a creditable scenario that would result in anything more serious than denial of service because of the interaction with the crew and all the checks and balances in the processes.

The present ISS design does not involve encrypting the downlink from the station to the Moscow or Houston Mission Control Centers (MCCs). The link between the two MCCs is also not encoded. It would be beneficial to have an independent threat assessment of these links. Unfortunately, the National Security Agency (NSA) is prohibited by law from giving counsel on foreign systems.

Ref: Findings#14and#15

NASA's security efforts involve finding or developing security tools, training NASA employees in security, conducting vulnerability testing at NASA Centers, reporting and recording all incidents, and developing cryptographic techniques. Several Centers are involved in supporting activities. An Integration Team has been formed, reporting to the NASA Chief Information Officer (CIO), that coordinates these activities. One of the first things the team did was to acquire tools that help with intrusion detection and analysis of systems for security vulnerabilities. At one Center, over 11,000 vulnerabilities (no actual intrusions, just ways they might have occurred) were detected. NASA plans to have a third party conduct a vulnerability test on each of the NASA Centers, a wise decision that should be pursued as rapidly as possible. This will take some time. In the interim, critical programs already underway should initiate their own third party vulnerability analyses.

The training requirements for use of new security tools are daunting. Systems administrators who handle dozens of different kinds of systems, program managers, and the users all must become familiar with and use good practices and tools. At present, much effort is going into development of training materials. It will be 2001 before they are in full swing. NASA should prioritize the training deployment so the most critical systems are covered as quickly as possible.

The Public Key Infrastructure (PKI), with selectable Digital Encryption System (DES) or triple-DES encryption, will be at the core of the information technology security system. It is based on a two-key encryption system—one public and one private—for each registered user. The PKI ensures information privacy, data integrity and signature authentication. The cost to deploy it to all NASA employees and selected contractors (100,000 certificates) is relatively modest. To date, NASA has purchased 20,000 certificates. PKI is expected to be operational throughout NASA by the end of FY2000. Documents can be encrypted at a selectable level of security, at the discretion of the author. It is planned that all employees will use it. Deployment on an experimental basis is beginning. Use of the tool is voluntary at present; even if required, getting all individuals to remember to comply is likely to be difficult. Also, licenses were obtained only for NASA employees, not NASA contractor personnel. This raises the concerns that it will be difficult to obtain uniform usage across all levels of employees and that leaving it optional to the contractors compromises the security that could be achieved.

Ref: Finding#16and#17

Obsolescence of the Space Shuttle avionics suite is a key issue. Some devices and components will soon become unsupportable. Original Equipment Manufacturers (OEMs) are leaving the government markets for the commercial markets. Mission requirements changes in communications, instrumentation, processing, and display are projected to exceed the capacity of current systems, and improvements are necessary to achieve operational goals. To address these issues, NASA has established the Avionics Upgrade Architecture Team (AUAT) and charged it with analyzing the situation and recommending necessary upgrades.

One of the avionics issues that has long concerned the Panel is the General Purpose Computer (GPC) system. While the Panel is now comfortable that the GPC hardware can be maintained until 2020, improvements are necessary if it is to accommodate the many anticipated software changes. The AUAT's analysis of the Central Processor Unit (CPU) and memory utilization suggests that unless something is done to off-load functionality or stop new increases in functionality, the GPC software will exceed the CPU and memory capacity by 2010. Previous efforts to limit Space Shuttle software growth have not been successful. The Panel believes that Space Shuttle software cannot be maintained within the GPC memory limits until 2020 without off-loading some functions.

The AUAT has developed an excellent plan that can relieve the GPC memory problem by moving some functions from the GPCs to new mission computers. The key to the effectiveness of the proposed mission computer architecture is the use of the existing Aerospace Ground Equipment (AGE) interface to provide a dual-ported memory. This would create an image of the GPC memory for the mission computer system. When combined with the AGE interface, the mission computer system allows many functions to be off-loaded from the GPC. This frees up memory and CPU capacity for software expansion in the GPC. The mission computer and the use of the AGE are part of the Block I avionics upgrade.

The AUAT's plans call for the use of three mission computers in order to achieve redundancy. Specific functions to be off-loaded from the GPCs to the mission computers have yet to be determined, although display functions will be among the top candidates. Eventually, the AUAT plans to consider moving "Crit 1" functions to the mission computers. That approach concerns the Panel. It is a significant departure from the current configuration which has proved successful in nearly 100 flights. Extensive testing would be required to achieve equivalent confidence in such a change.

Ref: Finding#18

The ISS program includes significant flight and test hardware and software development by the International Partners (IPs). Initially, maintenance of the source code will be accomplished under the control of the concerned IP. Responsibilities for the longer term, however, are not clear. The long-term support of the International Partners with respect to software source code is essential to the safe operation of the ISS and the resolution of any software-related anomalies. NASA must ensure that agreements to provide long-term support for the ISS, especially software systems, are in place and adequately cover source code and anomaly resolution.

F. AERO-SPACE TECHNOLOGY

Ref: Finding #19

While there has been some increase in NASA investment in aviation safety, overall funding falls short of supporting the goals and objectives of the Nation's aviation safety program. For example, examination of aging aircraft phenomena and techniques for amelioration or correction thereof have been all but terminated. Likewise, the effort to examine failure modes of composite structures has been significantly slowed. Similarly, efforts at finding new methods of non-destructive testing have been given low priority. Tire research has been abandoned and innovative cockpit visibility system development markedly set back. While some of these efforts remain the subjects of individual laboratory research, none benefit from the prestige and visibility brought by the status of such projects as the High Speed Research program and the Advanced Subsonic Technology aircraft. Projects such as these drive the smaller efforts which, in turn, are the keys to enhanced aviation safety. NASA should identify those elements of the eliminated programs which had the potential to improve aviation safety and cover them elsewhere.

Ref: Finding **#20**

The Panel is concerned that there is inconsistent definition of Center Directors' responsibility for and role in aviation flight readiness, flight clearance, and aviation safety review board matters. In certain instances, critical decisions are left to relatively junior NASA employees or to contractors. The Dryden Flight Research Center (DFRC) has an outstanding system, both on paper and in practice. This system should be used as a model by all other Centers and Center Directors to ensure proper involvement in aviation flight readiness, flight clearance, and aviation safety review board matters.

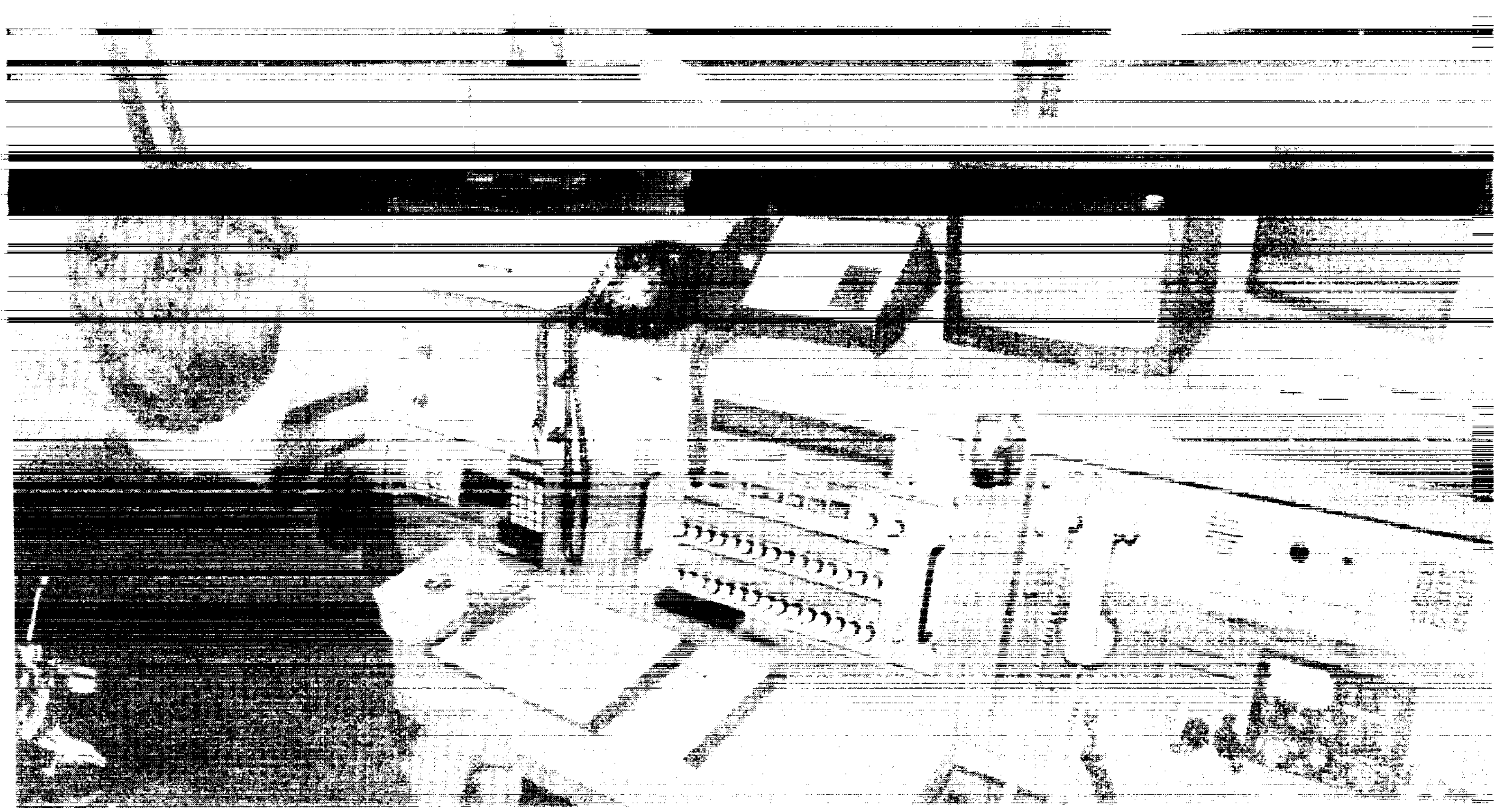
Ref: Finding#21

The responsibility for safety between NASA and the contractor when contractor aircraft and payloads are utilized is not well defined. Often, the rationale is that since contractor aircraft are operated under FAA certification procedures, NASA involvement is not required. The Panel does not agree with this rationale. In the event of an incident, NASA (or other Government personnel) could be charged with responsibility and, in any event, it will be a "NASA incident." One example is the recent Perseus Unoccupied Air Vehicle (UAV) accident wherein the flight termination system (FTS) failed. It had first been assumed that the design and implementation of the system were the contractor's responsibility, but when the FTS failed and the aircraft left the range, it became a Government problem. A potential for a similar, and even more disastrous, problem is in the Stratospheric Observatory for Infrared Astronomy (SOFIA) program. A central and precise definition of responsibility is needed. DFRC, NASA's Center for Flight Excellence, now has an excellent procedure which could serve as the model for better defining these responsibilities for all of NASA.

Ref: Findings#22,#23,and#24

The SOFIA project is still in its early phases, thus the Panel has no immediate safety concerns. There are potential problems in the long-term, however. For example, the project is a virtual hodgepodge of overlapping functions and responsibilities, ostensibly pointed toward flight of a large telescope some years in the future. NASA-operated Moffett Federal Airfield will be the home base of SOFIA operations, and the Ames Research Center (ARC) has responsibility for the program. The prime contractor under Ames' aegis is Universities Space Research Association. United Airlines (UAL) and Raytheon Corporation are supporting contractors. Currently underway is a five-year process for acquisition, modification, refurbishment, and certification of a Boeing 747SP aircraft. Airworthiness certification, reportedly, is the responsibility of both NASA and the Federal Aviation Administration (FAA) under Federal Air Regulation (FAR), Part 25, Supplemental Type Certificate. Maintenance will be governed by FAR Part 121. Operations will be governed by FAR Part 91. At some yet undetermined point, the NASA Ames Airworthiness and Flight Safety Review Board process will be implemented. This process had been all but abandoned with the transfer of most flight programs from Ames to DFRC. It is thus in need of early rejuvenation and exercise. Since UAL crews will operate the aircraft, UAL is also expected to conduct safety reviews. Meanwhile, as modifications to accommodate the telescope proceed, the affected flight operations community has been ignored. Consequently, not only are inappropriate procedures liable to become a fait accompli, but also flight system updates desirable for reducing workload and risk could well be overlooked. Some examples are flight management, navigation, and safety systems, such as the latest Traffic Alerting and Collision Avoidance System (T-CAS) and Reduced Vertical Separation Minima (RVSM) qualification. Finally, and most importantly, NASA and UAL flight operations personnel must be made a part of the SOFIA team and participate in all relevant matters beginning immediately.

IV. Appendices



IV. Appendices

Appendix A

AEROSPACE SAFETY ADVISORY PANEL MEMBERSHIP

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Dunlap and Associates, Inc.

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Former Deputy Chief of
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MS. SUSAN M. BURCH
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MS. VICKIE B. SMITH
Secretary
NASA Headquarters

Appendix B

NASA RESPONSE TO ANNUAL REPORT FOR 1998

SUMMARY

NASA responded on July 19, 1999, to the "Findings and Recommendations" from the *Annual Report for 1998.* NASA's response to each report item is categorized by the Panel as "open, continuing, or closed." Open items are those on which the Panel differs with the NASA response in one or more respects. They are typically addressed by a new finding, recommendation, or observation in this report. Continuing items involve concerns that are an inherent part of NASA operations or have not progressed sufficiently to permit a final determination by the Panel. These will remain a focus of the Panel's activities during 2000. Items considered answered adequately are deemed closed.

Based on the Panel's review of the NASA response and the information gathered during the 1999 period, the status of the recommendations made in the *Annual Report for 1998* is presented on the following pages.

Finding/Recommendation #1: ***Continuing*** - Despite high-level attention to workforce issues within NASA, a lifting of the hiring freeze, and some relief to OSF centers, several realities remain: continuing critical skill deficits in many locations, a continuing (although stretched out) downsizing at the OSF centers, and a seeming incapacity to hire young "fresh-out" engineering talent.

Finding/Recommendation #2: ***Continuing*** - Work pressures, coupled with downsizing and critical skills shortages, continue to make training and cross-training initiatives difficult to undertake fully in some situations, resulting in a work environment that stretches the capabilities of persons assigned to particular jobs.

Finding/Recommendation #3: ***Continuing*** - Project management training resources are being strengthened across NASA. These initiatives are generally of high quality and are welcomed in the field centers. However, this intensified effort is still in its early stages and has achieved limited impact in the field.

Finding/Recommendation # 4: ***Continuing*** - NASA's response is very encouraging. The intent to look beyond standard metrics is a good one. The expansion of the definitions related to close calls also suggests a productive shift in thinking. Nevertheless, at this point only plans exist.

Finding/Recommendation # 5: ***Open*** - Although the NASA response concurs with the recommendation, the supporting material is quite vague. Metrics have been developed and plans are in place, but there is no mention of how much of the paper will be addressed or on what timetable. There is a suggestion that new initiatives will solve the problem, but no concrete evidence.

Finding/Recommendation #6: ***Closed*** - Logistics recognizes the problem areas and is working the problems.

Finding/Recommendation #7: ***Closed*** - A comprehensive response.

Finding/Recommendation # 8: ***Closed*** - The response is basically a straightforward agreement with the recommendation.

Finding/Recommendation #9: ***Closed*** - All hardware and software for MEIT has been certified.

Finding/Recommendation #10: ***Open*** - NASA's response states that the primary purpose of the simulations is to check out the ***interfaces*** to other devices being tested in the MEIT. This is a different issue than the ***fidelity of the overall*** simulation which was the topic addressed in the finding and recommendation.

Finding/Recommendation #11: ***Closed*** - The Flight Crew Operations Directorate agrees that each flight crew should be actively involved in testing early in the hardware development and crew training cycles.

Finding/Recommendation #12: ***Open*** - The CRV procurement has been delayed by lack of funding. In addition, it appears that the Soyuz program is behind schedule and may not be able to supply the vehicles as previously agreed.

Finding/Recommendation #13: ***Open*** - The plans for CRV certification and human-rating are not yet available for assessment.

Finding/Recommendation #14: ***Continuing*** - While NASA's response reflects a significantly heightened sensitivity to the issue of radiation protection, the various radiation protection efforts are just beginning.

Finding/Recommendation #15: ***Closed*** - The NASA response indicates an appreciation for the importance of supporting research in radiation health physics.

Finding/Recommendation # 16: ***Closed*** - The issue is minor and has been surfaced.

Finding/Recommendation #17: ***Closed*** - A satisfactory response.

Finding/Recommendation #18: ***Closed*** - The justification for not acquiring additional U.S. SAFER units is technically reasonable.

Finding/Recommendation #19: ***Closed*** - A satisfactory response.

Finding/Recommendation #20: ***Continuing*** - NASA responds that the value of the EVA R&T Program is recognized, but implies that the scope of the program is budget constrained.

Finding/Recommendation #21: ***Closed*** - A satisfactory response.

Finding/Recommendation #22: ***Continuing*** - The NASA efforts to qualify a 2-hour pre-breathe protocol are underway.

Finding/Recommendation #23: ***Closed*** - Activity regarding EMU shielding has been initiated.

Finding/Recommendation #24: ***Closed*** - The NASA response justifies sustaining the EVA Ground Rule regarding simultaneous EMU/ORLAN EVA operations.

Finding /Recommendation #25a: ***Continuing*** - NASA has misunderstood the thrust of the Panel's comment relative to redundancy in the initiation function for the SAFER. There was no implication that two identical, redundant initiator systems should be provided, but rather that an alternate redundant system should be considered.

Finding/Recommendation #25b: ***Open*** - The finding was addressed to all NASA centers that use NASA Standard Initiators (NSIs). The reply appears to be limited to JSC and is adequate for that Center. The item should not be considered closed until other users of the NSI have been canvassed.

Finding/Recommendation #25c: ***Continuing*** - Testing with non-flight-type hardware was called for and used despite being contrary to generally accepted practice. It is commendable that the new circuit was properly tested with flight-type hardware, but this does not provide assurance that future testing will follow this example.

Finding/Recommendation #26: ***Closed*** - NASA indicates that the FAA is engaged.

Finding/Recommendation #27: ***Continuing*** – The NASA plan appears solid; the Panel is awaiting the results of software verification and other testing.

Finding/Recommendation #28: ***Continuing*** – The X-33 and X-34 programs are still maturing, and the range safety plans have yet to be definitized.

Finding/Recommendation #29: ***Continuing*** – NASA is taking steps in the right direction on the Space Shuttle GPC issues, but the program is not yet funded.

Finding/Recommendation #30: ***Closed*** – NASA's response states that they do not need to generate an I-load dependency matrix because the dependencies are verified as part of the certification process.

Finding/Recommendation #31: ***Closed*** – NASA has concurred with this recommendation and undertaken actions to follow the recommendation to provide a more robust lockout capability in CLCS.

Finding/Recommendation #32: ***Continuing*** – NASA concurs with the recommendation and has begun an action to deal with it, but it will take significant time to complete.

Finding/Recommendation #33: ***Closed*** – NASA concurs and has committed to follow this recommendation prior to flight of the ISS MMU.

Finding/Recommendation #34: ***Continuing*** – NASA has stated that the Russians will provide their source codes, but that other IPs will not because doing so would compromise their proprietary agreements with their contractors. Thus, the problem remains.

Finding/Recommendation #35: ***Continuing*** – NASA concurs with the recommendation and has initiated action to follow it. Results will take some time.

Finding/Recommendation #36: ***Closed*** – NASA states that this is already being done utilizing an Integrated Process Team approach.

Finding/Recommendation #37: ***Closed*** – NASA has concurred with the recommendation and taken action to incorporate a more secure uplink.

National Aeronautics and
Space Administration

Office of the Administrator
Washington, DC 20546-0001

JUL 19 1999

Mr. Richard Blomberg
Chairman
Aerospace Safety Advisory Panel
1010 Summer Street
Stamford, CT 06905-5503

Dear Mr. Blomberg:

In accordance with your request after our February 4, 1999, meeting, enclosed is NASA's response to the Section II, "Findings and Recommendations," from the Aerospace Safety Advisory Panel (ASAP) Annual Report for 1998.

The ASAP's efforts in assisting NASA to maintain the highest possible safety standards are commendable. Your recommendations are highly regarded and continue to play an important role in risk reduction in NASA programs.

We thank you and your Panel members and consultants for your valuable contributions. ASAP recommendations receive the full attention of NASA senior management. In particular, I expect that NASA's Office of Safety and Mission Assurance will track resolution of these issues as part of their role in independent assessment.

We welcome the continuance of this beneficial working relationship with the Panel.

Sincerely,

Daniel S. Goldin
Administrator

Enclosure

1998 AEROSPACE **SAFETY** ADVISORY **PANEL** REPORT

Findings, **Recommendations,** and **Responses**

Finding **#1**

Budget and personnel ceiling constraints on the hiring of engineers, scientists, and technical workers are moving NASA toward a crisis of losing the core competencies needed to conduct the Nation's space flight and aerospace programs in a safe and effective manner.

Recommendation **#1**

Provide NASA's human space flight Field Centers, particularly KSC, JSC, and MSFC, with the budgetary resources and administrative flexibility needed to strengthen their human resource capabilities.

Response

NASA concurs with the recommendation; and, we fully recognize the near heroic efforts at each of our installations that have brought us within striking distance of our downsizing targets.

At the beginning of fiscal year 1993, the NASA employment level was 24,900 FTE. As a result of the March 1993 Executive Order to reduce Federal Civilian FTE by 100,000, the NPR recommendations and additional OMB directed cuts in 1994, NASA received an out-year target of 20,906. Additional budget reductions occurred that required us to initiate the Zero Base Review, which was completed in 1995. The ZBR recommended an FY 2000 FTE level of 17,488. Since that time we have carefully managed an FTE reduction to a planned 18,545 FTE for FY 99 and 17,970 for FY 00. Our final "go to" target is now 17,574 FTE for FY 04. Currently 7 of our 10 Centers are at or below our lowest "go to" numbers. To NASA's credit, our accomplishments were achieved without resort to the ravages of a reduction-in-force. Voluntary losses to date include in excess of 4,500 buyouts, 1,300 early outs, and more than 800 inter-center transfers.

As a result of the downsizing challenges, we provided relief to the OSF Centers in the FY 00 budget process as follows: FY 99-153 FTE; FY 00-110 FTE; FY 01-103 FTE; FY 02-59 FTE; and, FY 03-68 FTE. This relief has enabled the innovative use of temporary and extended term appointments, as well as increasing the number of permanent hires available to fill critical skill positions. In addition, we are currently reviewing their request for additional relief, as identified in the recent Core Capability Assessment (CCA). OSF management has proposed several augmentation and/or hiring models that address both short and long term needs regarding replacement and enhancement of critical workforce competencies. One objective of the current CCA review is to help chart a strategy that will provide the OSF Centers with the requisite flexibility to attract and retain the core competency talent pool necessary to ensure safe mission and program success.

Finding#2

Shortfalls in workforce training within both NASA and USA, caused by downsizing and the related difficulty of hiring new people to fill skill shortages, can jeopardize otherwise safe operations.

Recommendation#2

NASA and USA should review critical skills training and certification requirements and institute programs to ensure the full proficiency of the workforce and the safety of the products being released.

Response

NASA concurs in the recommendation and, in cooperation with USA, has already reviewed certification requirements for flight controllers, training instructors, and other key operating positions. Training plans and certification requirements for critical positions have been documented and maintained. For example, the management role in launch countdown and landing is supported by a well-defined training and certification plan. NASA and its contractors are continually reviewing critical skills training and certification requirements to ensure controls are in place to validate and ensure employee proficiency. Quality initiatives are being developed to provide improved processes for cross training, automated training tools, inline automated certification validation, and enhancements in the closed loop verification of operators and system operational performance.

Meanwhile, training capacity for new employees, both NASA and contractor, has been increased through intensive simulator training at a new USA "training academy." A saturation-type training environment has been designed to improve training at the beginning of the regular certification process and produce employees better qualified for critical process work.

In training and orientation programs, NASA emphasizes the priority of safety and the responsibility of employees to voice their concerns about inadequate assurances of safe products.

Finding#3

The combined effect of workforce downsizing, the recent hiring freeze, and the SFOC transition, especially at KSC, has raised the possibility that NASA senior managers in the future will lack the necessary hands-on technical knowledge and in-line experience to provide effective insight of operations.

Recommendation#3

NASA should develop and promulgate training and career paths, with a special focus on providing hands-on technical knowledge and experience, so that NASA's future senior managers will possess the range of skills and experience required for effective insight of the SFOC.

Response

NASA concurs in the recommendation and is intensifying and refocusing its efforts in training and in support of career development at all levels.

At the operating level, NASA managers are instructed to plan and to take advantage of all opportunities to obtain operational experience through audit, surveillance, and other interfaces to provide hands-on experience to NASA personnel. These include, in addition to the simulator training discussed in the response to Recommendation #2:

- co-op assignments partnered with contractor systems engineers,
- direct observation or procedure review of critical tasks
- management of Shuttle launch countdown, launch, and landing/recovery
- participation in flight and ground systems development and enhancements
- processing mid-decks, utilization payloads, and partial Shuttle payloads
- participation in contractor testing, and anomaly resolution
- ensuring adequately designed, tested, and assembled hardware

Additionally, employees are provided cross training and specialized training as needed and strongly encouraged to take advantage of program related training.

The key to developing future generations of senior managers is to provide hands-on experience, with progressively more responsible assignments through one's career. Both NASA and the contractors continually seek improvements in the succession planning and preparations for the next generation of supervisors and managers. Special consideration is given to assuring that broad training and hands-on operational/technical job assignments and opportunities are consciously addressed for promising candidates for future senior management positions. NASA's training philosophy also emphasizes on-the-job work experiences supplemented by classroom instruction, participation in outside academic programs and industry through assignments in such private sector organizations as Boeing, Newport News Shipbuilding, and USA.

At the agency planning level, the training budget has provided for an increase of 20% for the Office of Space Flight from FY1997 through FY2000. Current agency Program Operating Plan (POP) guidelines call for funding training at 2-3.25% of salary levels, an extremely generous ratio for government and rivaling progressive private sector organizations.

The NASA Academy of Program and Project Leadership (APPL) is building on ten years of educational and developmental activities and is striving to facilitate the flow of current knowledge and techniques to the full engineering and science workforce. APPL is making available information and automated tools on-line and seeking to develop expert systems. APPL is also working directly to support intact teams with information and techniques and attempting to better organize case studies and archives into a more effective knowledge base.

The APPL program is also adding an Accelerated Leadership Option to the Project Management Development Process (PMDP) which will enable NASA engineers to obtain a Master's of Science in Engineering and Management degree from MIT. APPL is continuing and expanding a multifaceted program of classroom work, developmental work assignments, and dissemination of information and guidance.

Finally, NASA is well along in an update of its Leadership Development Model; documenting the technical, managerial, and executive competencies required to direct the work of the agency through the foreseeable future. This model will guide the scope and emphasis of training and development programs, including a new approach to succession planning, to ensure that NASA's leaders at all levels have the knowledge and skills to meet their responsibilities.

Finding#4

It is often difficult to find meaningful metrics that directly show safety risks or unsafe conditions. Safety risks for a mature vehicle, such as the Space Shuttle, are identifiable primarily in specific deviations from established procedures and processes, and they are meaningful only on a case-by-case basis. NASA and USA have a procedure for finding and reporting mishaps and "close calls" that should produce far more significant insight into safety risks than would mere metrics.

Recommendation#4

In addition to standard metrics, NASA should be intimately aware of the mishaps and close calls that are discovered, followup in a timely manner, and concur on the recommended corrective actions.

Response

NASA agrees with the recommendation. In addition to standard metrics, NASA is intimately aware of the mishaps and close calls and is directly involved in the investigations and approval of corrective actions. Current requirements contained in various NASA Center and contractor safety plans include procedures for reporting of mishaps and close calls. These reports are investigated and resolved under the leadership of NASA representatives with associated information being recorded and reported to NASA management. NASA is intimately aware of and participates in the causal analysis and designation of corrective action for each mishap. Additionally, NASA performs trend analysis of metrics as part of the required insight activities.

Definitions relating to "close call" have been expanded to include any observation or employee comment related to safety improvement. Close call reporting has been emphasized in contractor and NASA civil servant performance criteria and a robust management information system is being incorporated to monitor and analyze conditions and behavior having the potential to result in a mishap. Various joint NASA/contractor forums exist to review, evaluate, and assign actions associated with reported close calls. As an example, the KSC NASA Human Factors Integration Office leads the NASA/Contractor Human Factors Integrated Product Team (IPT) in the collection, integration, analysis, and dissemination of root cause and contributing cause data across all KSC organizations. The KSC Human Factors IPT is also enhancing the current close call process which includes tracking of mishaps with damage below $1000 and injuries with no lost workdays. The SSP has revised it's Preventive/Corrective Action Work Instruction to include mandatory quarterly review of close call reports. Several initiatives are in place to increase awareness of the importance of close call reporting and preventive/corrective action across the SSP and the supporting NASA Centers and contractors.

Under this new approach to close call reporting, a metric indicating an increase in close call reporting and preventive action is considered highly desirable as it indicates an increased involvement by the workforce in identifying and resolving potential hazards. Care is taken in over emphasizing the number of close calls reported as a performance metric to prevent reluctance in reporting. NASA is working hard to shift the paradigm from the negative aspects of reporting close calls under the previous definition to being a positive aspect of employee identification of close calls under the new definition.

Finding #5

A principal cause of Space Shuttle processing errors is incorrect documentation ("paperwork").

Recommendation #5

NASA and USA must place increased priority on determining error sources, causes, and corrective actions for inadequacies in the documentation on which Space Shuttle processing is based and develop a management system that drastically reduces the time that it takes to incorporate paperwork changes.

Response

NASA concurs with the recommendation. NASA and USA have established metrics to identify the types of errors and error sources in the processing documentation. During daily interface, NASA and USA discuss these metrics and perform causal analysis to identify the need for corrective action. For critical procedures, USA has implemented a check and balance in the work instruction generation process to increase the procedure quality before it is worked. Additionally, NASA and USA have an initiative to reduce the complexity of work procedures, increase the procedure standardization, and reduce the time for paperwork generation for work not requiring engineering disposition.

More importantly, USA is developing, as a high priority, a paperless system. Specifically, the Ground Operations organization at KSC is implementing an integrated on-line system that ensures total process rigor and mitigates the potential for human error in accomplishing space flight work. This system incorporates recognized "best practices" for authoring work documents including on-line review and approval, and the ability for authors to automatically update and incorporate work document deviations. Required checks and balances are inherent in the system to maintain the integrity, safety and quality of both flight and ground work performed. Work documents will clarify user understanding by incorporating enhanced explanations with in-line graphics, sound and video where required. The goal of this activity is to ensure that a properly certified person, utilizing the right work instructions, has safely accomplished all required work.

Finding#6

While spares support of the Space Shuttle fleet has been generally satisfactory, repair turnaround times (RTAT's) have shown indications of rising. Increased flight rates will exacerbate this problem.

Recommendation#6

Refocus on adequate acquisition of spares and logistic system staffing levels to preclude high RTAT's, which contribute to poor reliability and could lead to a mishap.

Response

NASA concurs with the recommendation. During calendar year 1998, RTAT's for both the NASA Shuttle Logistics Depot and the original equipment manufacturer fluctuated, but at year's end, the overall trend was downward through concerted NASA and vendor efforts. These efforts are aimed at providing better support at the current flight rate and for higher flight rates in the future. Logistics is working to find innovative ways to extend the lives of aging line replaceable units (LRU's) and their support/test equipment. Logistics has initiated the Space Council (an industry group with 11 other company executives addressing such topics as verification reduction, ISO compliance, and upgrades) to assure the supplier base continues its outstanding support to the SSP. Examples of LRU's being evaluated and enhanced include: Star Trackers, auxiliary power units, inertial measurement units, multifunction electronic display system (MEDS), Ku-band, orbiter tires, and manned maneuvering units.

NASA/KSC Logistics and USA Integrated Logistics have made progress on a long-term supportability tool. The tool will provide information, including historical repair trend data for major LRU's, RTAT's, and "what if" scenarios based on manipulation of factors (e.g., flight rate, turnaround times, loss of assets, etc.) to determine their effect on the probability of sufficiency. This will be a tool, not a substitute, for human analytical decision making.

Finding#7

NASA aircraft used for both Space Shuttle operations and astronaut training are increasingly out of date and, in several respects, may be approaching the unsafe. This is noticeably so in the case of the Shuttle Training Aircraft (STA) and T-38 aircraft.

Recommendation#7

Continue to execute and accelerate as much as possible the current plans for the modernization and safety assessment of astronaut training aircraft.

Response

NASA believes that the current aircraft used as astronaut training aircraft are maintained in a safe condition. NASA remains committed to safe operation of all the training aircraft. Measures to ensure that the NASA T-38's and STA's used for astronaut training are maintained in a safe configuration and in good material and structural condition are in place. A summary of current efforts is as follows:

T-38: NASA's approach to maintaining and modernizing the T-38's is two-fold. The first approach consists of maintaining and upgrading the fleet in consonance with the USAF programs. (The USAF Air Training Command plans to use the T-38 for flight training to 2020 and beyond.) This includes engine component upgrades, replacement of structural members, including entire wings, and comprehensive nondestructive inspections at prescribed intervals. Additionally, a 1995 NASA contracted limited damage tolerance assessment study confirmed that the aircraft structures can be maintained with standard inspection criteria at intervals. The second approach encompasses NASA unique programs that are tailored to the specific use of the NASA T-38's for the astronauts' space flight readiness training. NASA unique programs include:

1. An Avionics Upgrade Program which modernized the communications and navigation systems, replaced high failure rate and outdated avionics, and added a weather radar, a flight management system, an altitude alerter, and modern controls and displays. This program has been completed on the T-38 operational fleet and has resulted in a redesignation of the USAF T-38A to the NASA T-38N. Intended follow-on avionics enhancements, as they become practical and economically acceptable for the T-38N, includes modification to a Global Positioning Satellite (GPS)-based flight management system and the incorporation of the terminal collision avoidance system.

2. Modified engine inlets to increase the takeoff performance and the margin of safety of the aircraft over the standard configuration. A successful flight test program on the

prototype aircraft has been completed, and the T-38 corrosion control and structural modification team at El Paso, Texas, has completed the first pilot production aircraft.

3. Replacing the T-38 ejection seats with state-of-the-art seats that will meet the full range of astronaut anthropometrics and are highly reliable, zero-altitude/zero-air-speed capable.

4. A just completed flight test of an engine ejector modification designed to improve the in-flight range of the T-38. This modification should enhance both efficiency and flight safety.

NASA will continue to evaluate new programs and seek new initiatives to meet the requirements as they evolve, such as adding avionics for compatibility with the future free flight concept in the air traffic control system.

STA: NASA has four STA's and one spare Gulfstream II (GII) that will be modified into an STA when it is either required by the Shuttle flight rate or in the event that one of the four STA's becomes unusable.

In regards to STA maintenance, the initial aircraft maintenance and inspection program developed by the aircraft manufacturer, Grumman, in concert with NASA engineers included a short interval comprehensive nondestructive inspection program. That maintenance program was designed to ensure close monitoring of the structural health and material condition of the STA, which was and is operated in a much more demanding flight regime than the corporate GII aircraft. Furthermore, a 1993 and 1994 NASA contracted effort with Science Applications International Corporation resulted in the determination that the STA fleet can operate safely within the established flight training profiles and that structural integrity can be monitored through the ongoing inspection program.

Modernization of the aircraft includes recent avionics systems upgrades with an incorporated differential GPS approach guidance system and the modification of the Shuttle simulation system to include the orbiter MEDS to provide astronaut pilot orbiter landing training for MEDS-equipped orbiters.

Based on the basic STA GII remaining service life and the NASA maintenance program, there should be ample service life remaining on the four aircraft to provide astronaut training well into the second decade of the 21st century. However, repair and component costs due to systems obsolescence or frequency of structural repairs could conceivably indicate a need for either systems redesigns or an earlier selection of a replacement aircraft type.

Finding#8

The use of simulated Space Shuttle launch and flight operations for training and rehearsal has proven to be an effective technique for enhancing safety and efficiency and is especially valuable in the case of special or rarely performed procedures or after a long hiatus of effort.

Recommendation#8

Simulation-based training should be included in difficult or infrequent Space Shuttle operations whenever feasible. This type of training is especially needed after there has been a significant hiatus in performing an operation.

Response

NASA concurs with the recommendation. NASA and USA have beneficially increased simulation-based training at KSC. The pursuit of a separate simulation training room and simulation team will allow NASA and USA to further increase the number of simulations that can be performed each flow. Additionally, KSC will use the new collaborative engineering environment to enhance simulation capabilities.

Finding#9

Some hardware is being used in MEIT before it has completed qualification testing. Software is also often used before its verification and validation is complete. In both cases, modification to the hardware or software may be required before certification is completed, thereby potentially invalidating the results of the initial MEIT testing.

Recommendation#9

When it makes sense to deliver hardware or software to system-level testing such as MEIT before qualification/certification is complete, the effect of any qualification-induced changes must be carefully evaluated for implications for regression testing. Final testing should always be run with validated software and qualified hardware.

Response

NASA concurs with the recommendation and notes that the ISS Program requires regression evaluation for all modifications performed on flight hardware to assess whether certification, acceptance, or integration testing results are invalidated and must be performed again. The final flight configuration will be verified by regression testing as well as acceptance, mission sequence, end-to-end, and integration tests.

The Space Station and Shuttle Payloads Office at KSC (Code NN) utilizes Flight, Flight Equivalent and GSE hardware and software for MEIT that has been certified through ISS Program Office control boards and panels for these tests. The boards and panels also specify regression tests with flight units when required through the directives they provide. The NN MEIT test schedules currently have regression tests planned for modified or repaired hardware units and revised software per ISS Program Office control board and panel directives and requirements.

Finding#10

MEIT is the highest level of integrated testing available before committing ISS elements to launch. In order to produce valid results, this testing requires a high level of fidelity in emulators/simulators used in place of missing components.

Recommendation#10

The ISS Program should ensure that high-fidelity simulations of on-orbit components are used in the MEIT and that the configurations of those simulators are validated to be in agreement with what has actually been orbited.

Response

NASA concurs with the recommendation. The node emulator for MEIT I was built as certified GSE as was the Lab Emulator for MEIT II and III. Emulator design requirements include the emulated flight article's ICDs to the elements under test in MEIT. Activation/Validation and integrated testing confirms emulators meet the emulated flight article's interface requirements and compares emulator performance with the flight article's performance in similar testing. The primary objective of these tests is to certify the emulators act like the flight article for the interfaces under test. The emulators are under configuration management (CM) control and any updates to the flight elements will be checked for potential impacts to the emulators.

Finding#11

Astronaut crew participation in testing improves fidelity of the test and better familiarizes the crew with systems and procedures.

Recommendation#11

NASA should continue to involve the crew in integration testing and do so more heavily and at an earlier stage.

Response

NASA concurs with the recommendation. The Flight Crew Operations Directorate (FCOD) at JSC is making every effort to ensure that astronauts are actively involved in hardware and software testing of Space Station components at all phases of their development. FCOD heartily concurs that this involvement needs to continue at an early stage and with a high level of participation.This involvement is accomplished through the technical assignments that are filled by astronauts who are not assigned to a specific mission and by the assigned flight crews responsible for the assembly of the hardware on orbit. Traditionally, flight crews are assigned about 1 year ahead of time for a shuttle mission.

In the case of Space Station assembly missions, an attempt has been made to assign crews at least a year and a half ahead of time so that they are actively involved in the development of the on orbit procedures and the test and checkout of the hardware. Early involvement ensures that crews are able to make engineering inputs based on operational experience to correct problems before they result in time consuming and difficult on orbit workarounds.

All test activities are tracked by the Vehicle Integration Test Team (VITT) within FCOD. To accomplish this, personnel are assigned the responsibility to monitor the hardware at the various sites where it is being built, including overseas sites, as well as at the Kennedy Space Center.These personnel provide the astronauts with the current status of the hardware, coordinate crew visits to the sites and ensure that astronauts are participants in all critical tests.

Additionally, the increment crews that will actually be living on the station after it is constructed have been made active participants in the test and checkout of the hardware while it is still on the ground.

FCOD will continue to ensure that this crew involvement continues and is not just limited to Space Station assembly missions but also encompasses Orbiter upgrades, the Crew Return Vehicle, payloads, and any future program that requires astronaut participation.

Finding#12

The current ISS requirement is for a single Crew Return Vehicle (CRV). Crew safety over the life of the ISS requires the availability on orbit of two CRV's, both of which is capable of accommodating the entire crew. The Soyuz capsule, designated as the interim CRV, does not have a full crew capability. Also, it is uncertain that sufficient Soyuz capsules and their launches will be available to supply the needs of the ISS.

Recommendation#12

NASA should accelerate its program to develop and deploy two full-crew CRV's and take whatever measures are necessary now to ensure the availability of sufficient Soyuz capsules and launchers until the CRV's are ready.

Response

The item remains open and under assessment. The ISS Program has assessed the need and feasibility for a second CRV on-orbit aboard the Space Station. A Tiger Team, led by the Astronaut Office, was chartered to assess the overall effectiveness. The Tiger Team presented its findings to the Lead Center Director and the Associate Administrator for Space Flight, who requested that additional analysis be performed in alternative configurations.

NASA is engaged in on-going discussions with the Russian Space Agency regarding the acquisition of additional Soyuz vehicles. Due to the current Russian economic problems, NASA closely monitors the status of the Soyuz production required to support the ISS at the manufacturer, Energia. NASA is engaged in on-going discussions of the procurement of additional goods and services from RSA. The procurement will provide the cash flow necessary to sustain the production levels of Soyuz vehicles that the ISS requires until the CRV is available. These discussions will continue in the overall context of determining Russia's ability to satisfy its commitment as an international partner.

Finding#13

Plans calling for availability on orbit in early 2003 of a U.S. CRV based on the X-38 technology demonstrator are highly ambitious. Although much of the X-38 technology is off the shelf, there are numerous features that rely on yet-unproven approaches.

Recommendation#13

NASA must not allow the limited CRV development time to comprise the conduct of a thorough risk assessment and testing program.

Response

Concur. The new CRV acquisition strategy requires the developing contractor to take responsibility/accountability for the CRV's flight readiness. The CRV RFP Synopsis asked candidate contractors about CRV risks. None identified 2003 launch readiness as a significant risk. For government developed technologies (i.e. parafoil and OML aero) the test programs are ongoing and will be demonstrated with flight tests.

Although much of the X-38 design is based upon off-the-shelf technology, it is recognized that features such as the parafoil landing system are unproven. Where this is the case, extra testing is being performed to certify and human rate these systems. The extensive parafoil test program at the Yuma Proving Ground is an example of the rigorous testing of an unproven design. The last several successful parachute tests are beginning to show the fruits of this approach. Once parafoil testing has reached a point which has a proven safety and maturity of its design, the parafoil design will not be allowed to be changed by the contractor in their CRV design.

Safety and Mission Assurance play an important role in the X-38 Phase 1 activity. Each contractor will be required to develop at least an S&MA Plan, Risk Management Plan, Vehicle Certification Plan, Vehicle fault tolerance studies & recommendations, Failure Mode, Effect, and Criticality Analysis, and Human Rating Assessment for their CRV design. Quality of these S&MA tasks will play a major role in the selection by NASA personnel of one contractor to perform the Phase 2 task of building the CRV.

Finding#14

In the ASAP Annual Report for 1997, the Panel expressed concern for the high doses of radiation recorded by the U.S. astronauts during extended Phase I missions in *Mir.* Subsequent and continuing review of this potential problem revalidates that unresolved concern. The current NASA limit for radiation exposure is 40 REM per year to the blood-forming organs, twice the limit for the U.S. airline pilots and four times the limit for Navy nuclear operators (see also Finding #23).

Recommendation#14

NASA should reduce the annual limit for radiation exposure to the blood-forming organs by at least one half to not more than 20 REM.

Response

NASA concurs with the recommendation. However, in keeping with the "as low as reasonably achievable" (ALARA) radiation protection principle, NASA is proposing a set of administrative spaceflight exposure limits which are significantly below the NCRP recommended annual limits. The administrative limits are designed to improve the management of astronaut radiation exposures and ensure that any exposures are minimized. The proposed administrative BFO exposure limits range from 5 cSv (REM) for a one month exposure period to 16 cSv (REM) for a twelve month exposure period. These limits have been proposed for inclusion in section B14 of the Flight Rules and are currently awaiting concurrence from Energia and the Russian Space Agency.

The National Council on Radiation Protection and Measurements (NCRP) developed these limits in 1989 for NASA. The NCRP is a congressionally chartered organization responsible for developing radiation protection limits. The NASA Administrator, OSHA, and the Department of Labor approved these limits.

NASA has adapted 30 day and annual dose limits of 0.25 Sv and 0.5 Sv, respectively. The purpose of these limits is to prevent acute health effects, such as nausea, vomiting, etc. NASA also maintains career limits intended to limit the probability of cancer below 3% excess cancer mortaility. These career limits are comparable to the US career limits for other radiation workers. Furthermore, the annual limits also serve to spread out career radiation exposure over time.

The NCRP completed a re-evaluation of astronaut exposure limits in 1998 using the most recent results from longitudinal studies of Japanese atomic bomb survivors. Currently, the NCRP has a draft report undergoing full NCRP review and approval, which is expected to be released in the fall of 1999. When this report is released, NASA will consider its recommendations and, if appropriate, will proceed to implement any recommended reductions.

Finding#15

By virtue of the several ongoing programs for the human exploration of space, NASA is pioneering the study of radiation exposure in space and its effects on the human body. Research that could develop and expand credible knowledge in this field of unknowns is not keeping pace with operational progress.

Recommendation#15

Provide the resources to support more completely research in radiation health physics.

Response

NASA concurs with the recommendation. The funding for radiation research has been augmented over the past couple of years. Expanding support for radiation health physics research will benefit the mitigation of effects of space radiation and the accurate determination of organ doses. NASA's Space Radiation Health Program supports basic research in radiobiology and biological countermeasures. The Radiation Health Program has initiated efforts to provide reference dosimetry capabilities for flight dosimetry at Loma Linda University and Brookhaven National Laboratory. A phantom torso is being used to assess organ doses on Shuttle and ISS. JSC has initiated efforts to improve measurements of the neutron contribution to doses in LEO. These efforts include increasing opportunities to use neutron detector systems and the development of a high-energy neutron detector by the National Space Biomedical Research Institute (NSBRI). Improved understanding of radiation transport properties of the GCR and neutrons can be used to develop shielding augmentation approaches for crew sleep quarters and exercise rooms on ISS.

Finding#16

Many deployable structures on the ISS and satellites on which astronauts must work during EVA's use pyrotechnic initiators.There is often no simple way for an EVA astronaut to know by visual inspection whether or not an initiator has fired when a structure has failed to deploy properly.

Recommendation#16

NASA should develop and require the use of pyrotechnic initiators that leave clear visual evidence that they have fired.These "fire-evident" initiators should be required for all applications that may be encountered by an EVA astronaut.

Response

The NASA Standard Initiator (NSI) is required for use in all electrically initiated pyrotechnic systems whether the application may be encountered by an EVA astronaut or not.The NSI does not provide any means for external visual inspection of fired condition when it is installed in a mechanism. Currently, the only test being performed to verify that the initiator fired, without disassembly of the pyrotechnic mechanism, is to measure firing circuit resistance before and after firing.This function can be built into the firing unit. It is not foolproof however, since it cannot detect a smart short.To date this has not been a problem with the NSI since in nearly 100,000 units produced and certified there are no documented failures.That is why the NSI carries a reliability of 0.999 at a 90% confidence level.All failures to fire have been traced directly to the electrical wiring, connectors, firing unit or flight computer. Breaks in the electrical firing circuit can be identified by a pre-fire circuit resistance check.

The desire of visual identification is further compounded by the physical location of the initiator. In many applications it is located internal to a mechanism and is not directly accessible or visible. For those applications where it is external to the mechanism it is still not visible since half the device is torqued into the mechanism and the other half is covered by the electrical connector. Stretching the device to make a portion of it visible would require a re-design and re-qualification of the initiator at an extremely high cost as well as making it larger and heavier in a size and weight conscious world.

Two types of visual indicators have been considered for incorporation into the initiator.The first is a temperature sensitive tape that could be placed on the outside of the initiator body that would change colors due to temperature rise generated from firing the initiator.This is not considered practical.The temperature rise of the NSI body is small and further effected by heat sinking of the mechanism it is inserted into. The actual temperature rise that would result is lower than the temperature rise generated by direct solar radiation. It would be unknown whether the color change was due to the initiator firing or the sun. The tape would also not be visible due to coverage by the electrical connector without redesign of the initiator body.

The second possibility of a visual indicator is a pop-up pin that would be pressure driven by the NSI firing. Incorporating the pin into the NSI would be both complex and expensive. The NSI is a hermetically sealed device, there is no way to incorporate a pop-out pin without violating the hermetic seal. The size of the NSI would have to be greatly expanded to accommodate the pin/piston which would have to withstand pressures from 600 psia to as high as 25,000 psia. The pin/piston orientation would also affect the pressure output and function time of the initiator.

One final consideration that is very significant is that there are over 1000 pyrotechnic devices and mechanisms that have been flight qualified and certified to function with the NSI. Those devices are in repeated use on numerous crewed and uncrewed programs. The intrusion of a new initiator would not only be a reduction in reliability but would require re-qualification of associated components at a tremendous cost. Currently, there are no plans to pursue recommendation #16.

Finding#17

In the event that a primary crewmember is unable to fly on an assigned ISS mission, current plans call for substituting a crewmember from a backup crew. Backup crewmembers do not, however, train extensively with the primary crew.

Recommendation#17

If backup crewmembers are to be substituted individually to the primary crew, then those crews should conduct some meaningful degree of joint training.

Response

NASA concurs with the recommendation. Clearly, crews that are going to be flying together need to spend time together on the ground. Our current training process includes numerous training sessions where the backup crew is in attendance with the prime crew. And while there are not specific simulator sessions with joint or mixed crews, more importantly, the Expedition 1 and 3 crews do spend quite a bit of time together (as do the Expedition 2 crew and their backups, Expedition 4).

The current policy of the organization is that backup crews can be substituted for the prime crew right up until launch. However, the decision will be made on a case-by-case basis whether one person or the entire crew is changed out. Our current plan does make provision for the former to occur.

Finding#18

The EVA project lacks sufficient operational assets to meet unplanned contingencies. There are no spare Extravehicular Mobility Units (EMU's). Only five U.S. Simplified Aid for EVA Rescue (SAFER) flight units will be available to meet a requirement to maintain three units on orbit. In addition, only four Russian SAFER units are planned.

Recommendation#18

To meet contingencies that are almost certain to arise, additional EMU's and SAFER units or their critical long lead components should be procured as soon as possible.

Response

NASA concurs with the ASAP recommendation. With respect to the EMU, the inventory of life support system (LSS) hardware will be 14 (13 Class I and 1 Class II) by October 1999. Exceedences to our supply begin in 2000. In order to achieve a 90 percent probability of sufficiency, NASA must increase its inventory by two LSS's. NASA plans on addressing this issue within the Program Operating Plan (POP) 99. We plan to upgrade the current Class II LSS to Class I and upgrade the certification unit to Class II. This will increase our inventory to 15. NASA also plans to go forward with the recommendation to procure an additional LSS to achieve 16 LSS's.

Additionally, the current space suit assembly (SSA) flight hardware models predict SSA demand beyond the current inventory of 15. The demand peaks at 23 for one month, but there are 15 months where it is at 18 through 2004. The current plan is to procure hardware to 18 through the POP 99. SSA hardware shortages can be determined once crewmembers are selected. The lead times for SSA hardware are such that once shortages are determined, specific hardware shortages can be procured.

The current training model for the EMU predicts demand not to exceed the procured inventory of 10; therefore, sufficient inventory exists for training.

With respect to the USA SAFER, NASA concurs with the ASAP recommendation on obtaining critical long lead components. In fact, the majority of the long lead components have already been procured. These components are expected to support the USA SAFER flight units for their 7-year life.

NASA can normally support the requirement to maintain three USA SAFER flight units on orbit with five flight units in service. The current rotation plan utilizes two of the flight units to accommodate rotation of back-to-back missions where the turnaround time is approximately 1 month. With one flight unit out of service, four USA SAFER flight units can be rotated to maintain three units on orbit for 92 percent of the flights per the International Space Station (ISS) assembly sequence dated February 22, 1999.The remaining 8 percent of the flights can also be supported with contingent coordination ahead of time to reduce the turnaround time from approximately 1.5 months to approximately 1 month.

Another option was already planned to deal with the margin in the rotation of five USA SAFER flight units. In order to increase the USA SAFER logistics margin, an extension of the 1-year certification will be assessed based on flight performance. Being able to leave the units on orbit longer will allow the rotation rate to decrease sufficiently to eliminate any problems with having one unit out of service. Data will be collected for analysis immediately after the flight units are declared fully operational.

At the present, additional USA SAFER flight units are not needed for the following reasons:

1) The rotation of five flight units can fully support the flight requirement; 2) the rotation of four flight units can support the flight requirement for at least 92 percent of the current ISS assembly flights; 3) the turnaround time can be reduced for special cases; and 4) the on-orbit certification is expected to be extended with additional flight data. However, in the event a USA SAFER flight unit is not available for any reason, the EVA crew is trained to use the two-fault tolerant tethering scheme to meet the safety requirement.This tethering scheme is fully certified and has been used successfully during several EVA's, including those on the recent STS-88 mission.

Lastly, with respect to the Russian SAFER, NASA has revised its plan and will now produce five flight units, rather than four, in order to support the logistics model consistent with the USA SAFER plan.

Finding #19

The three available sizes of EMU planar Hard Upper Torso (HUT) units will accommodate crewmembers from the 40th percentile female to the 95th percentile male. Assumptions were made regarding the ability of crewmembers to upsize or downsize to fit the three available HUT sizes and operate safely and effectively in them.

Recommendation#19

To validate the ability of crewmembers to actually use the various available HUT sizes, crewmembers in each of the several size combinations/configurations should be required to perform normal and emergency functions in training mockups to demonstrate that full capability is available to each.

Response

NASA agrees with the ASAP recommendation, as it is part of our standard process. Crewmembers are sized in 1-G and suit fit is verified during Neutral Buoyancy Laboratory (NBL) and vacuum chamber testing. Nominal suit fit capability is verified in the NBL, while emergency procedures are demonstrated under vacuum conditions using flight hardware.

Finding#20

The EVA Research and Technology (R&T) program has been highly successful, and its products have led to the development of significant safety and operational improvements to EVA hardware and procedures. Current funding for advanced R&T for EVA is extremely limited.

Recommendation#20

Restore the EVA R&T program to a level that will permit further development of not only near-term safety and operability improvements but also long-term products.

Response

NASA recognizes the importance of the EVA R&T program. The EVA Project Office maintains the EVA technology roadmap, and, when appropriate, makes recommendations to the existing Programs when it is prudent to pursue R&T development (e.g., reduced prebreathe protocol). Also, NASA continues to provide R&T funding support, prioritized against requirements from NASA Headquarters on an annual basis.

Finding#21

The safety implications of EVA training for U.S. and international partner astronauts in the Russian Hydrolab are not well understood. In particular, the implications of higher suit pressures and Russian bends protocols have not been thoroughly analyzed.

Recommendation#21

NASA should study the procedures used in the Russian Hydrolab to determine their safety and monitor all Hydrolab testing when U.S. astronauts are involved.

Response

NASA concurs with the ASAP recommendation. The Gagarin Cosmonaut Training Center (GCTC) Hydrolab facility is an established cosmonaut training facility. The GCTC Hydrolab is a neutral buoyancy training facility. The facility is an above-ground, circular tank with a maximum depth of 12 meters; however, a false floor limits the maximum useable depth to 10 meters. The false floor can be raised above the water level for positioning mockups, walk-through training, or hardware repair and modification. The standards applied to the Hydrolab's design and operations are not NASA standards but instead the Russian equivalent.

NASA safety and medical representatives have performed a safety assessment of the GCTC Hydrolab facility utilizing the NASA Safety Standard for Underwater Facility and Non Open Water Operations, NSS/WS 1740.10, and other JSC requirements as a guide for directing the safety evaluation of the Hydrolab. The assessment focused on the suit hardware and its interfaces, including the effects of suit pressure/physiological depth, facility systems that support training, and pool deck systems.

The Hydrolab is an acceptable facility for conducting operations with NASA personnel and equipment with one caveat, NASA medical personnel have requested that the Russians demonstrate proficiency in the use of the hyperbaric chamber at the GCTC. This demonstration was planned to occur prior to April 30, 1999. Beyond the hyperbaric chamber proficiency demonstration, the condition of this training facility does not pose a direct or unreasonable risk to U.S. personnel or vital NASA equipment. NASA and GCTC have agreed to several procedural and hardware related enhancements that will be made to the Hydrolab facility to increase the overall safety. JSC safety and medical representatives will be available in the Hydrolab as part of the test team during all suited operations in the Hydrolab and will continue to monitor safety and take further action as required.

For additional information, the complete agreement is documented in EVA Project Office memo XA-99-031, dated February 18, 1999, subject: Gagarin Cosmonaut Training Center (GCTC) Hydrolab Safety For U.S. Personnel.

Finding#22

There is an initiative to modify the prebreathe protocol for EVA operations on the ISS. The target is a 2-hour prebreathe from any pressure with the same or better bends risk than the protocol currently used in Space Shuttle operations.

Recommendation#22

Prior to authorizing any reduction in prebreathe protocol for EVA on the ISS, NASA should conduct a study to ensure that there is no increase in the risk of bends associated with the special circumstances of the proposed new protocol.

Response

NASA concurs with the ASAP recommendation, and believes that the recommended study efforts have already been initiated. In 1997, the EVA IPT initiated a Prebreathe Reduction Program (PRP) to address the risk of decompression sickness (DCS) associated with reduced prebreathe protocols. The PRP Team developed a detailed 2-year plan to: 1) Develop and test an operationally implementable 2-hour prebreathe protocol; 2) perform a detailed risk assessment of acceptable DCS risk to provide prospective accept/reject criteria so that there was a clear metric by which to judge the success or failure of the laboratory trials; 3) develop improved methods for treating DCS on orbit; and 4) develop flight rules to document in advance the specific actions that would be taken to manage a DCS contingency should one occur.

Items 2, 3, and 4 from above form the NASA "DCS Risk Definition and Contingency Plan." Effort required by that plan has been completed and favorably reviewed by an external review committee chaired by Dr. C. J. Lambertsen. Accept/reject criteria developed from the above plan was used in an extensive, multi-phase laboratory-testing program of an operationally implementable 2-hour prebreathe protocol. This effort was initiated in November 1997 as a multi-center effort led and managed by NASA and involving three external laboratories (Duke University, the Canadian Defense and Civil Institute of Environmental Medicine, and the University of Texas Hermann Hospital). A review of the multi-phased laboratory-testing program results and the entire PRP project conducted by medical experts of the International Partners (the Multi-Lateral Medical Operations Panel subcommittee for EVA) resulted in a committee recommendation that the 2-hour protocol should be safe to implement for EVA's from the ISS. Furthermore, additional internal and external reviews of the laboratory data are planned for June 1999. Pending the recommendations of that review, NASA believes there to be no increase in the risk of bends associated with the special circumstances of the proposed new protocol, and the 2-hour protocol will be implemented for operations on ISS Flight 7A, which includes the first U.S. space walks from the ISS joint airlock.

The PRP Team has also developed a 5-year operational research plan with the goals of providing a better understanding of the underlying science of DCS in microgravity and the possibility of further reductions in prebreathe without compromise to safety. This 5-year research program will include four external laboratories, including the Brooks Air Force Base Armstrong Laboratory and the onsite NASA JSC facilities.

Finally, NASA is committed to continued investigative/research efforts to address any relevant data obtained from past, current, or future testing in order to assure no increase in the risk of bends associated with the special circumstances of current or proposed new protocol.

Finding#23

The greatest potential for overexposure of the crew to ionizing radiation exists during EVA operations. Furthermore, the magnitude of any overexposure cannot be predicted using current models.

Recommendation#23

NASA should determine the most effective method of increasing EMU shielding without adversely affecting operability and then implement that shielding for the EMU's.

Response

NASA concurs with the ASAP recommendation. Efforts are in work to both minimize radiation exposure and to obtain data relative to increased EMU shielding. Efforts to minimize EVA doses include coordination to minimize the South Atlantic anomaly passes between the Space Radiation Analysis Group, Medical Operations, EVA Office, and Flight Director. Monitoring of EVA doses on ISS will include the use of crew dosimeters and the external vehicle charge particle detector systems (EVCPDS). Developing active dosimeters to be worn inside the EMU that would augment the EVCPDS as a warning system and improve the monitoring of crew doses is being considered. A proposal to deploy an external tissue equivalent proportional counter prior to EVCPDS deployment on ISS Increment 8A that would provide improved EVA dose enhancement warning capability is being developed. JSC in collaboration with the Lawrence Berkeley National Laboratory is assessing ways to measure the shielding capacity of the EMU and the Russian Orlan suit using proton and electron exposure facilities at Loma Linda University. These measurements would support a study of the effectiveness of increasing EMU shielding. In addition, the development of an electron belt enhancement model and improved solar particle event forecasting and Earth geomagnetic field models that would provide large improvements in predictive capabilities for the occurrence of enhanced EVA doses is being considered.

Finding#24

EVA ground rule 4.3.2.12, "No Simultaneous EMU/Orlan ISS Extravehicular Activity," is constraining and reduces flexibility.

Recommendation#24

NASA should reexamine this ground rule and consider a criterion for selecting either an EMU or the Orlan suit for a particular EVA based on the specific requirements of the EVA or the specific crewmembers performing the EVA.

Response

NASA concurs with the intent of ASAP recommendation. Current mission planning requires one-fault tolerance for both EVA hardware and personnel. Additionally, all EVA crewmembers (a minimum of three will be onboard the vehicle) will be trained to operate in both the U.S. EMU and Russian Orlan. Therefore, for example, a crewmember planning to perform an EVA in the EMU would have the following fault tolerance capability: 1) primary EMU; 2) backup EMU; then 3) Orlan. Fault tolerance alone precludes the need to plan for a simultaneous EMU/Orlan EVA; however, the primary rationale for not planning for this is the safety risks associated with two different suit procedures/parameters during a single EVA.

Primary spacesuit monitoring responsibility will reside with the country responsible for the development of the hardware (i.e., Russians will have primary responsibility for the Orlan and Americans for the EMU). Therefore, if both the Orlan and EMU were in use during a single EVA, a shared responsibility for monitoring spacesuit performance exists. If an emergency occurs, there are increased safety risks that result from the shared responsibilities. Based on the increased safety risks and given the fault tolerance capability defined above, NASA does not believe it is prudent to plan for the option to use both the EMU and Orlan simultaneously.

Finding #25

The NASA Standard Initiator (NSI) on a SAFER unit tested on STS-86 on October 1, 1997, did not activate because of a marginal design of the activating power supply. As a result, the unit could not function. The certification testing for the firing circuit did not identify the power supply inadequacy. Also, an inadequate NSI emulator was used for most of the original SAFER certification (qualification) and acceptance tests (see also Finding #14).

Recommendation #25a

The design and implementation of flight systems critical to safety and mission success should, at least, provide redundancy for system startup.

Response

NASA concurs with the ASAP finding that the NSI drive circuit of the USA SAFER was marginal in its design to the point where the drive circuit failed to activate the NSI during a demonstration on STS-86. The failure was due to lack of margin within the subsystem to drive the NSI and not due to lack of redundancy (a backup subsystem) to the subsystem. Adding redundancy (a backup subsystem) to drive the NSI would not resolve the lack of margin as both the primary and backup subsystems would still fail to drive the NSI without sufficient margin. This condition was addressed by addition of a new NSI circuit with increased margin to fire the NSI on demand. In addition the new NSI contains redundant components where possible.

The USA SAFER is categorized as emergency hardware and is designed for use only after the EVA crewmember had inadvertently separated from structure due to a tether failure or a tether disconnection. The combination of the tether and USA SAFER provide a functional redundancy to each other and a fail-operational system, which can sustain one failure in the tether (functional after one failure) and still retains the capability to continue with the EVA. A subsequent failure of the tether (two failures) and a functional USA SAFER provide a fail-safe system, which still retains the capability to successfully terminate the mission by using the USA SAFER to bring the inadvertently-separated EVA crewmember back to safety. Once the USA SAFER is needed to perform self-rescue in its role as the fail-safe device, its failure to perform due to any reason would result in loss of the EVA crewmember. Because the USA SAFER is to provide the fail-safe capability, as the functional redundancy to the tether, it was designed as a single-string system. As such, redundancy was not required for all subsystems and components. Adding redundancy to the activation subsystem alone would not increase the probability of saving an inadvertently separated crewmember since other critical subsystems (propulsion and mechanism) are still single-string. NASA will evaluate redesigning the next generation SAFER to be fully redundant in critical functions.

Recommendation#25b

All NASA Centers should review the design requirements for reliable activation of the NSI and assure they are adequate to be communicated to their suppliers, especially those who are responsible for the design of firing circuits.All designs currently using NSI's should be reviewed to assure that the firing circuits are adequate and have been appropriately tested.

Response

NASA agrees with the ASAP recommendation. The new USA SAFER NSI circuit employs the capacitive discharge approach which has been well proven by the SSP. Peer reviews were held to evaluate the new circuit design, and a series of tests were performed with the complete flight circuit. Also, the Engineering Directorate's Pyrotechnic Subsystem Manager performed a comprehensive review of all known uses of the NSI to ensure an acceptable design existed and that appropriate certification/ acceptance tests had been accomplished. Lastly, a User's Guide (JSC-28596) for the NSI was developed to assist developers in selecting the appropriate NSI, designing the appropriate NSI drive circuit, and testing the complete NSI subsystem.

Recommendation #25c

Qualification tests of safety-critical equipment must use flight-quality hardware. Any exceptions must require high-level program approval.

Response

NASA concurs with ASAP recommendation to use flight-quality hardware to support qualification testing. The new USA SAFER circuit certification was completed with the successful firing of 15 flight NSI's consecutively.

Finding#26

Achieving the objectives of the first of NASA's Three Pillars, Global Civil Aviation, requires greater involvement and support by the Federal Aviation Administration (FAA).

Recommendation#26

NASA should pursue further commitment from the FAA to participate in the first of NASA's Three Pillars, Global Civil Aviation.

Response

In 1998 and 1999 our commitment to the President's aviation safety challenge was met through early safety products from each of our Base Research and Technology programs. In 2000, the Aviation Safety focused program begins, in addition to some investment in the Base. The planning for our investment was done in complete harmony with the FAA's activities—both their research investment, as well as their operational efforts. Implementing the results of our collaborative research and technology efforts are fundamental to achieving our safety goal. The recent commitment between the FAA Administrator, Ms. Garvey, and Mr. Goldin committed our two agencies to our two agencies' goals. Further, our Aviation Safety Program is part of the Safety Joint Working Group, and reports to the FAA-NASA Executive Committee that oversees all cooperative activities between the two agencies. The Program also works as partners with FAA to implement the program and will maintain close coordination with the Department of Defense and other government agencies. And, significantly, the Safety Program Manager is member of Commercial Aviation Safety Team and General Aviation Joint Steering Committee—government-industry leadership groups developing and managing overall National safety strategies. NASA aviation safety research and technology efforts therefore complements both FAA and industry activities as a coordinated overall effort.

Finding#27

The X-34 technology demonstrator program faces safety risks related to the vehicle's separation from the L-1011 carrier aircraft and to the validation of flight software. Moreover, safety functions seem to be distributed among the numerous contractors, subcontractors, and NASA without a clear definition of roles and responsibilities.

Recommendation#27

NASA should review and assure that adequate attention is focused on the potentially dangerous flight separation maneuver, the thorough and proper validation of flight software, and the pinpointing and integration of safety responsibilities in the X-34 program.

Response

Wind tunnel separation tests simulating the separation of the X-34 from the L-1011 have been successfully completed, using scale wind tunnel models of the X-34 and L-1011. The X-34 release mechanism is based on the flight-proven Pegasus release mechanism designed by Orbital Sciences Corporation. The A-1 vehicle will be flown in captive carry mode under the L-1011; additionally, the A-2 vehicle will be flown in dress rehearsal attached to the L-1011. The aerodynamic forces and flying qualities of the combined vehicles will be assessed during these flights.

The flight software will be carried through a thorough Verification and Validation testing process by Orbital Sciences Corporation. Performance tests of the X-34 navigation system (hardware and flight software) have already been conducted at the White Sands Missile Range using an aircraft platform. Subjecting the flight software to IV and V remains an option to the program if concerns about the software dictate.

In May 1998, Code Q conducted a detailed review of safety and mission assurance processes being used by the X-34 program, and found the existing processes in place at Orbital Sciences Corporation and its subs to be satisfactory. Recommendations from the review have been addressed, and are available for review. A follow-up review with Code Q and the X-34 Project Office was held on December 10, 1998.

Finding#28

Because X-33 and X-34 flight range safety is the responsibility of another agency, NASA may have a tendency to pay less attention to that aspect of the programs.

Recommendation #28

When NASA-sponsored vehicles are using a test range, NASA should not abdicate its responsibilities to ensure safe flight.

Response

The X-33 flight test profiles have met the long established requirements for flight safety for all military Ranges. Additionally, the flight test program has undergone scrutiny from all potentially impacted organizations, both private and government, through the public process for an Environment Impact Statement (EIS). All overflight routes, trajectories, and landing sites were included in the EIS analyses. The X-33 filed its Record of Decision on November 4, 1997.

Public law and Department of Defense regulations place Range safety responsibility in the hands of the Range Commander not NASA. The NASA X-33 Program Office is satisfying every Air Force Range requirement and risk analysis. NASA, as the user, is supporting the Range and is applying expertise from both Dryden Flight Research Center and Marshall Space Flight Center in every topic of flight and ground safety.

Finding#29

The Space Shuttle General Purpose Computers (GPC's) are outmoded and limit the ability to incorporate necessary software changes and hardware upgrades.

Recommendation#29

NASA should begin the process of replacing the Space Shuttle GPC's. As part of this effort, NASA should also modularize the flight software.

Response

The Space Shuttle Program is addressing the finding and recommendation identified by the ASAP. A review of the GPC and its flight software was performed in April 1998. Based on current estimates on GPC mean time between failures, the flight hardware and spares are expected to be available through at least 2016 (and likely significantly later). The flight software estimate on memory availability and usage has projected that memory capacity would be expected to reach its limit in the 2005-2006 timeframe.

A software architecture strategy as part of the overall SSP avionics upgrade effort is being developed which will mitigate the memory capacity concern. This strategy will partition the critical software such as flight control and guidance from software that requires periodic change. The result of this partition would allow those stable software functions like flight control to remain within the current GPC's while allowing those functions that frequently change to be migrated to a newer computer technology. The offloading of the software functions such as display processing and systems management from the current GPC's should permit current GPC memory capacity to remain acceptable through at least 2020. Additionally the software subject to frequent change would be located within a system, which will be designed to be more easily reconfigurable than the existing system.

In summary, a supportability concern does not exist for the current GPC's. Continued use of the existing GPC's and their established processes will maintain high levels of safety. Software partitioning involving the offloading of software functions to a more flexible system will provide sufficient memory availability for future GPC software changes. This approach will provide an evolutionary and a migration path to full GPC upgrade if it is later required.

Finding #30

There is no formal requirement that dependent Space Shuttle I-loads be recalculated or checked when an I-load patch is to be uplinked.

Recommendation #30

NASA should create a dependency matrix of all I-loads. Furthermore, it should assess its Space Shuttle and ISS procedures and ensure that they are all fully documented.

Response

NASA believes that we already meet the intent of the recommendation. Flight Operations processes and documentation ensures proper I-load change implementation for all flight design I-loads, including uplinkable I-loads. These procedures include positive verification that the selected or uplinked values do not violate subsystem, element, or integrated vehicle certification and that the update meets mission requirements. I-load dependencies are verified as part of the certification assessment.

Procedures for verifying I-loads to be uplinked vary. In some instances uplinked I-loads change vehicle response in a way that impacts several of the remaining I-loads; i.e., Day-of-Launch I-load Update (DOLILU). Those verification assessments include an analysis which uses a high fidelity computer model to simulate integrated vehicle response to the new I-loads. These simulations include models of the onboard flight software of sufficient detail to verify that all applicable I-load interactions are assessed. In other cases, specific I-load dependencies are evaluated.

A number of flight design uplinks involve an uplink of values that are generated and verified days or sometimes months before launch. These I-loads include vehicle navigation, targeting, and abort parameters. Verification procedures for these I-loads are identical to that used during the normal flight design template.

For all cases, procedures clearly specifying verification requirements including specific I-load dependency evaluations, as applicable, are in place and under configuration control.

Finding #31

Present plans depend on human procedures to achieve lockout to prevent inadvertent or unauthorized access to actual hardware when using the new Checkout and Launch Control System (CLCS).

Recommendation #31

NASA should use a computerized authorization to achieve lockout of commands to actual hardware from anyone not authorized to issue such a command in CLCS.

Response

NASA concurs with the ASAP recommendation. The CLCS Project will undertake a study with the Shuttle engineering community to determine how these lockouts could be implemented. The results will include a preliminary set of requirements for CLCS and other systems, such as the Shuttle Data Center and Simulation Systems, an operational risk assessment for implementing these changes, and a rough order of magnitude cost assessment for implementing these changes. The study will be completed in a timely manner so that implementation can be accomplished in time to avoid extensive revalidation of CLCS application software. Progress reports will be presented to the ASAP during their CLCS review meetings.

Finding#32

NASA does not have a plan in place to deal with the problem of maintaining the many commercial off-the-shelf (COTS) software development tools used in its programs.

Recommendation#32

NASA should develop a general strategy and provide programwide guidelines for addressing the maintenance of COTS tools.

Response

NASA concurs with the finding that no programwide plan exists addressing the maintenance of COTS software development tools. A programmatic action has been assigned to develop the usage requirements for COTS/modified off-the-shelf software including the associated development tools. These guidelines will document maintenance and selection guidelines to be used by all of the applicable program elements.

Finding #33

The planning process for computer upgrades for the ISS has begun. Several possible upgrades are being discussed, such as replacing the Mass Memory Unit, upgrading the processor, upgrading the compiler used, and replacing the Portable Computer Systems (PCS).

Recommendation #33

NASA should proceed with the upgrade of ISS computer components expeditiously. In particular, the replacement of the mass storage device with solid-state memory should be made as soon as possible.

Response

NASA concurs with the recommendation. A change request is currently being processed to retro-fit the solid state mass memory into the MDMs. The intent is to make the hardware change prior to flight of the MDMs.

Finding#34

Configuration management of ISS software does not include the source code for all of the elements being developed by the international partners.

Recommendation#34

NASA should strengthen the configuration control for ISS software to include software (source code as well as binary) and simulations produced by all international partners and vendors.

Response

NASA partially concurs with the recommendation, however, there seems to be some misunderstanding here.The source code for the Russian Service Module SM software is delivered to the SDIL. Some of the other partners, however do not deliver source code.This is based on their concerns that delivery of source code could compromise their contractor's proprietary data. From a configuration management viewpoint controlling the executable, which is what is loaded into the vehicle, is sufficient.The ISS has initiated discussions with all partners to reach agreement on what level of source code visibility is necessary to ensure adequate knowledge by the control centers for on-orbit anomaly resolution.

The SM simulation software has been somewhat dynamic as the SM software has matured during vehicle testing in Moscow. Now that testing is finishing and the SM moves to the launch site, the simulation will stabilize.The flight software and the simulations are obviously tightly linked and the simulations should typically be updated, as they are currently, in conjunction with the flight software. NASA is working to put in place an encrypted link for electronic transmittals.

Finding#35

The ISS presently has no programwide software development standards to manage software activities performed by NASA, its contractors, and the international partners.

Recommendation#35

The ISS program should establish programwide standards to aid in specifying, designing, developing, and managing all future ISS software projects. These standards can be as simple as a set of best practices.

Response

NASA concurs with the recommendation. To this point in the program Mil-STD-498 has been used as the basis for software development. However it has not been documented as the "ISS standard". Discussions have been initiated with all the partners to establish a program wide recognized standard.

Finding #36

Several software developments are on the critical path for launch and operation of the ISS. While some software elements have had the early involvement of a multi-disciplinary team that includes users and operators, many have not. The lack of user involvement results in increased schedule and safety risk to the program.

Recommendation #36

The ISS program should follow a concurrent engineering approach to building software that involves users and other key discipline specialists early in the software development process to provide a full range of perspectives and improve the understanding of requirements before code is developed.

Response

NASA concurs with the recommendation. The US portion of the ISS is structured around an Integrated Product Team approach. This approach did, and does, include specialists from users and operators during all phases of development. The international partner's development is followed closely by subsystem and operations working groups to enhance system understanding and involvement by system experts, crew, and operations personnel.

Finding#37

The recent compromising of the Data Encryption Standard (DES) suggests that the ISS command uplink may not be sufficiently protected.

Recommendation#37

NASA should engage the National Security Agency to conduct a thorough evaluation of the level of protection provided by the current system and proceed as rapidly as feasible with its plans for a more secure encryption system for the ISS. Potential vulnerabilities of the ground elements of the system should also be assessed.

Response

NASA concurs with the recommendation. The ISS Program Office has been working with the NASA HQ Security Office, the NSA and NIST to define an acceptable replacement for DES. The newly selected encryption standard for ISS is Triple-DES, as approved at the Avionics Software Control Panel on March 17, 1999. The target date to begin implementation is assembly flight 9A with completion at 13A.

Appendix C

AEROSPACE SAFETY ADVISORY PANEL ACTIVITIES

JANUARY–DECEMBER 1999

JANUARY

January 5–8, 1999 - Kennedy Space Center, Fact-Finding

January 22, 1999 - NASA Headquarters, International Space Station Uplink Encryption Meeting

January 28, 1999 - Marshall Space Flight Center, SRB Vendor Visit

January 28–29, 1999 - Johnson Space Center, Software Summit Meeting

FEBRUARY

February 4-5, 1999 - NASA Headquarters, ASAP Annual Meeting

February 23-24, 1999 - Kennedy Space Center, Space Shuttle Program Manager's Review

February 24-25, 1999 - Rocketdyne, SSME and ISS Power System Fact-Finding and SSME Vendor Visit

February 25, 1999 - NASA Headquarters, Testimony before the House Subcommittee on Space and Aeronautics

MARCH

March 2-3, 1999 - Ames Research Center, Review of Human Factors

March 12, 1999 - NASA Headquarters, Meeting with KSC Inspector General

March 23, 1999 - NASA Headquarters, Workforce Meeting

March 29-31, 1999 - Johnson Space Center, Fact-Finding

APRIL

April 21-22, 1999 - Johnson Space Center, Software Summit Meeting

April 29-30, 1999 - Johnson Space Center, Computer Team Fact-Finding

MAY

May 5, 1999 - Kennedy Space Center, STS-96 Flight Readiness Review

May 5-6, 1999 - Michoud Assembly Facility, Integrated Logistics Panel Meeting

May 12, 1999 - NASA Headquarters, Panel Administration

May 19-21, 1999 - Marshall Space Flight Center, Fact-Finding

May 24, 1999 - Johnson Space Center, Space Shuttle Program Manager POP 99 Review

May 26, 1999 - NASA Headquarters, Panel Administration

JUNE

June 7-9, 1999 - Kennedy Space Center, Plenary Session

June 17, 1999 - Kennedy Space Center, KSC Safety Day

June 21-22, 1999 - Langley Research Center, Fact-Finding

June 22, 1999 - Seattle, Washington, Boeing Space Group, IUS Fact-Finding

June 24-25, 1999 - NASA Headquarters, Fact-Finding

June 29, 1999 - NASA Headquarters, Fact-Finding

JULY

July 1, 1999 - NASA Headquarters, IUS Fact-Finding

July 6, 1999 - NASA Headquarters, IUS Fact-Finding

July 8, 1999 - Kennedy Space Center, STS-93 Flight Readiness Review

July 14-15, 1999 - Johnson Space Center, Crew Return Vehicle Fact-Finding

July 20, 1999 - Kennedy Space Center, STS-93 Launch

July 28, 1999 - NASA Headquarters, Fact-Finding

AUGUST

August 19-20, 1999 - NASA Headquarters, Fact-Finding

August 24-25, 1999 - Ames Research Center, Aero-Space Technology Fact-Finding

August 25-26, 1999 - Ames Research Center, Computer Team Fact-Finding

August 31, 1999 - Johnson Space Center, Radiation Risk Meeting

SEPTEMBER

September 1, 1999 - Johnson Space Center, Radiation Risk Meeting

September 8, 1999 - NASA Headquarters, Fact-Finding with Ames Personnel

September 15, 1999 - NASA Headquarters, Fact-Finding

September 22-23, 1999 - Johnson Space Center, Plenary Session

September 29, 1999- NASA Headquarters, Inspector General Meeting and ELV Meeting

OCTOBER

October 4, 1999 - Kennedy Space Center, Fact-Finding

October 5-6, 1999 - Dryden Flight Research Center, Fact-Finding

October 8, 1999 - Kennedy Space Center, ELV RL-10 ERB

October 12, 1999 - Marshall Space Flight Center, Workforce Fact-Finding

October 18, 1999 - NASA Headquarters, Fact-Finding

October 19, 1999 - Vandenberg Air Force Base, ELV Fact-Finding

October 26, 1999 - Ogden, Utah, Thiokol Space Operations, Fact-Finding

NOVEMBER

November 3, 1999 - NASA Headquarters, Workforce Fact-Finding

November 3-5, 1999 - NASA Headquarters, Plenary Session

November 9, 1999 - Johnson Space Center, Fact-Finding

November 16, 1999 - Kennedy Space Center, ELV Fact-Finding

November 16-17, 1999 - Johnson Space Center, Computer Team Fact-Finding

November 16-17, 1999 - Melbourne, Florida, Participate in 5th Annual Florida Space Launch Symposium

November 17-18, 1999 - Ogden, Utah, Thiokol Space Operations, Integrated Logistics Panel Meeting

November 18-19, 1999 - Kennedy Space Center, STS-103 Flight Readiness Review

November 29-30, 1999 - NASA Headquarters, Editorial Committee Meeting

DECEMBER

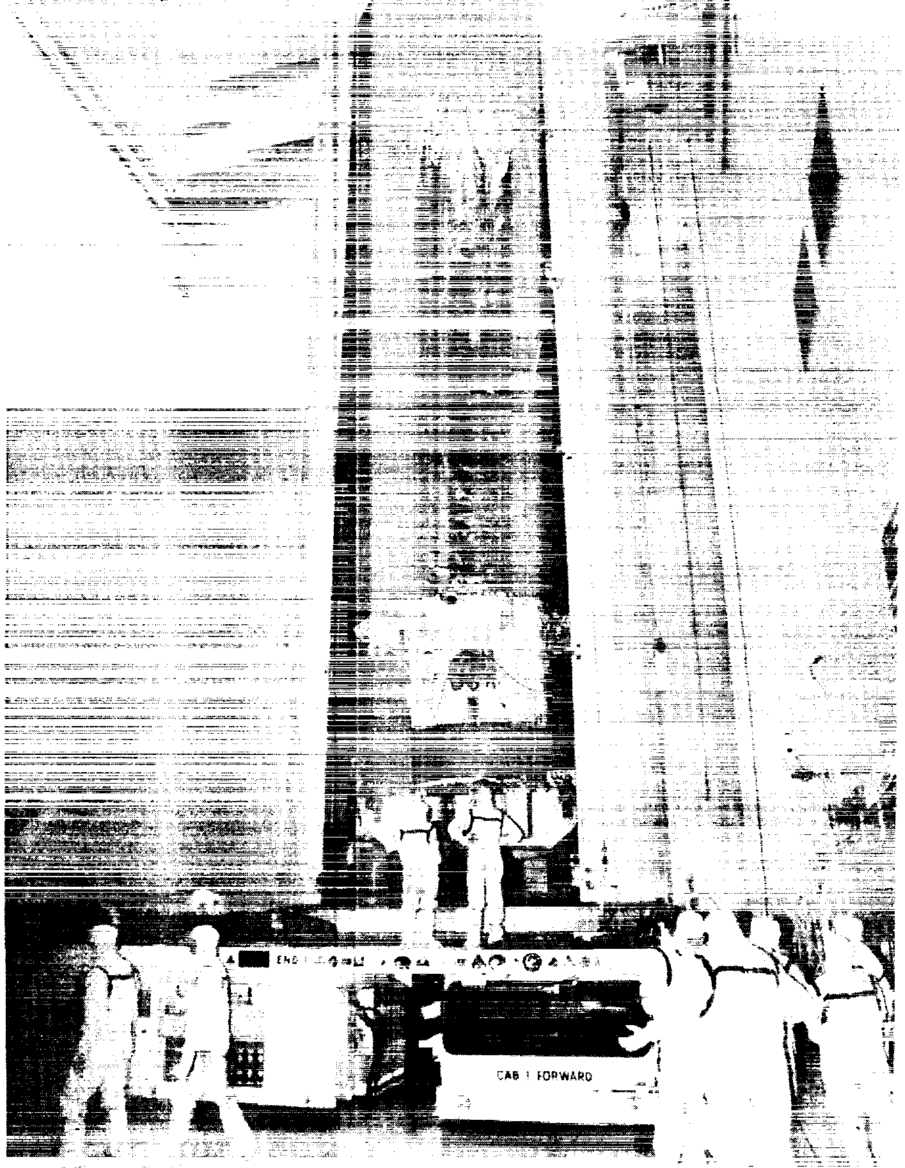
December 1, 1999 - NASA Headquarters, Editorial Committee Meeting

December 8, 1999 - Kennedy Space Center, United Space Alliance Independent Review of Orbiter Sub-Systems

December 9, 1999 - Kennedy Space Center, Deliberations on LH2 Recirculation Line

December 14, 1999 - NASA Headquarters, Editorial Committee Meeting and Telecon

December 16, 1999 - STS-103 Countdown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